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SUMMARY AND USE OF SELECTED FLUVIAL SEDIMENT-DISCHARGE FORMULAS

U.S. GEOLOGICAL SURVEY

Water Resources Investigations Report 89-4026

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SUMMARY AND USE OF SELECTED FLUVIAL SEDIMENT-DISCHARGE FORMULAS

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CONVERSION FACTORS

Inch-pound units used in this report may be converted to International system of units (SI) by using the following conversion factors:

Multiply inch-pound units	By	To obtain SI units
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
feet per second (ft/s)	0.3048	meters per second (m/s)
inch (in.)	25.40	millimeter (mm)
pound (lb)	0.4536	kilogram (kg)
pounds per second (lb/s)	0.4536	kilogram per second (kg/s)
pound per foot (lb/ft)	1.488	kilogram per meter (kg/m)
pound per square foot (lb/ft^2)	4.882	kilogram per square meter (kg/m^2)
pound per cubic foot (lb/ft^3)	16.017	kilogram per cubic meter (kg/m^3)
slugs per cubic foot	515.5	kilogram per cubic meter (kg/m^3)
square foot (ft^2)	0.0929	square meter (m^2)
square foot per second (ft^2/s)	0.0929	square meter per second (m^2/s)
ton per day (t/d)	0.9078	metric ton per day (t/d)

International system of units (SI) used in this report may be converted to inch-pound units by using the following conversion factors:

Multiply SI units	By	To obtain inch-pound units
liter per second (l/s)	0.03531	cubic foot per second (ft^3/s)
meter (m)	3.281	foot (ft)
millimeter (mm)	0.03937	inch (in.)
ton per cubic meter (t/m^3)	0.0312	ton per cubic foot (t/ft^3)
ton per second (t/s)	2205.0	pounds per second (lb/s)

To convert degree Celsius (°C) used in this report to degree Fahrenheit (°F), use the following equation:

$$°F = 9/5(°C) + 32.$$

SUMMARY AND USE OF SELECTED FLUVIAL SEDIMENT-DISCHARGE FORMULAS

H. H. Stevens, Jr. and C. T. Yang

ABSTRACT

Two versions of computer programs for inputting data and computing fluvial sediment discharge by five described bedload formulas and eight described bed-material formulas are presented. The FORTRAN 77 language versions are for use on the Prime computer, and the BASIC language versions are for use on microcomputers. A review of published formula-comparison studies indicate that the bedload formulas of Schoklitsch (1934) and Meyer-Peter and Müller (1948); and the bed-material formulas of Yang (1973) for sand and Ackers and White (1973), Engelund and Hansen (1967), and Yang (1984) for gravel are the most reliable. Suggested procedures are presented for formula selection when field data are available and when they are absent. Documentation and listings for both versions of the programs are included in the report.

INTRODUCTION

The selection of an appropriate discharge formula for fluvial sediment, hereafter called sediment, is very important in order to accurately predict sediment discharges in rivers and estuaries, particularly in areas where energy resources are being developed, or in waterways in which contaminents are associated with sediments. Numerous sediment-discharge formulas have been proposed in the literature, and extensive summaries compiled by Alonso (1980), American Society of Civil Engineers (1975), Bathurst (1985), Brownlie (1981), Schulits and Hill (1968), White, Milli, and Crabbe (1978), and Yang and Molinas (1982). This report describes 13 sediment discharge formulas, presents comparisons between measured and computed results from the formulas, and provides information to help select formulas for different flow and sediment conditions. Selection of the formulas was based on; 1) theoretical background, 2) extent of testing by original author and independent investigator(s), and 3) extent of use by engineers and researchers.

This report also describes two computer programs. Program DISDATA enables keyboard entry of discharge data and storage into a data file, and program SEDDISCH reads the data from the data file and computes the sediment discharge by all formulas selected by the user from the 13 described formulas. Both programs are written in FORTRAN 77 and MS-BASIC[1] for use on a variety of computers. An explanation of the text symbols and corresponding computer program variable names are presented in the section "text symbols and program variables". Program listings and examples of output from programs DISDATA and SEDDISCH are included at the back of the report in Supplemental Data Sections A through G.

DESCRIPTION OF FLUVIAL SEDIMENT-DISCHARGE FORMULAS

Fluvial sediment discharge rates depend on a large number of variables. Because of the wide variation in many of the influencing variables, most formulas have been developed based on one or two dominant variables such as water discharge, average flow velocity, water surface slope, shear stress, stream power, and unit stream power. Yang (1988) described the basic approaches used in the development of sediment transport formulas as deterministic, probabilistic, and regression.

Formulas derived from the deterministic approach assume there is an invariant correlation between dependent and independent variables. An advantage of this approach is that when values of the independent variables are given, sediment discharge rates or concentrations can be computed directly. A disadvantage of this approach is that if the assumed relation is inexact, does not exist, or exists only during certain conditions, computed results may be inaccurate. The general form of many early deterministic formulas is:

$$G_s = A\,(P - P_c)^B \qquad (1)$$

[1] Microsoft BASIC language developed by the Microsoft Corporation. The use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

where G_s - the sediment discharge;

A - a parmeter related to flow and sediment characteristics;

P - the independent variable, such as water discharge, mean velocity, water slope, shear stress, stream power, or unit stream power;

c - a subscript to denote the "critical" value of P at incipient motion; and

B - an exponent related to flow and sediment characteristics.

One well-known formula of this type is the Schoklitsch (1934) formula (See page 5).

Another approach used to develop sediment-transport formulas has been to base rates on predictions of particle motion derived from probability considerations. Equations to define the beginning and ceasing of sediment motion, as well as the average rate of sediment discharge can be formulated. Einstein's (1950) bedload function is the most prominent formula based on the probabilistic approach.

The third approach, regression analyses, is used mainly to obtain empirical relations between sediment discharge rates and some flow and sediment parameters. An advantage of using the regression approach is that it can give quick site-specific relations provided reliable data are available for analysis. A disadvantage is that the technique does not provide much physical meaning or explanation of the sediment-discharge process. A formula obtained purely from regression analysis can be applied only to conditions which are similar to those used in obtaining the regression formula.

Investigators have relied extensively on dimensional analysis. The usual approach is to correlate sediment concentration or a dimensionless transport rate with a principal, and perhaps other, dimensionless parameters. Examples of principal dimensionless parameters are the mobility number of Ackers and White (1973) combining shear stress and grain shear stress, and the unit stream power of Yang (1973) which combines velocity and slope.

Thirteen sediment-discharge formulas are included in this report. They represent some of the more commonly used formulas developed from the deterministic and probabilistic approaches. Because they may be restrictive in their application, formulas developed entirely by regression analysis are not included. The formulas are divided into two groups; five bedload discharge formulas, and eight bed-material discharge formulas. A summary of the sediment-discharge formulas presented in this report are given in Table 1.

Table 1.--Summary of sediment-discharge formulas presented in this report

Author of formula	Date	Bedload (B) or bed-material (B-M)	Type of formula[1]	Sediment type[2]	Sediment size[3]
Ackers and White	1973	B-M	D	S	S,G
Colby	1964	B-M	D	S	S
Einstein (bedload)	1950	B	P	M	S,G
Einstein (bed-material)	1950	B-M	P	M	S
Engelund and Hansen	1967	B-M	D	S	S
Kalinske	1947	B	D	M	S
Laursen	1958	B-M	D	M	S
Meyer-Peter and Müller	1948	B	D	S	S,G
Rottner	1959	B	D	S	S
Schoklitsch	1934	B	D	M	S,G
Toffaleti	1968	B-M	D	M	S
Yang (sand)	1973	B-M	D	O	S
Yang (gravel)	1984	B-M	D	O	G

[1] Deterministic (D) or Probabilistic (P)
[2] Single size fraction (S), mixture (M) or optional (O)
[3] Sand (S) or gravel (G)

First, the equation(s), terminology, and units (metric or inch-pound) proposed by the original author(s) are presented for each formula, then the final equations are expressed in inch-pound units except sediment size is expressed in millimeters (mm). A value of 2.65 is used for the specific gravity of the sediment (S_g).

Bedload Discharge Formulas

Five bedload discharge formulas are presented in this section. Bedload discharge is the discharge of sediment that moves in essentially continuous contact with the bed.

Schoklitsch Formula

Schoklitsch (1934) developed a bedload formula based mainly on Gilbert's (1914) flume data with median sediment sizes ranging from 0.3 to 5 mm. The basis for this formula, (Schulits, 1935) is that bed material begins to move at some critical discharge and that the bedload discharge is proportional to the rate of work done by the part of the tractive force in excess of that needed to overcome the resistance along the wetted perimeter. If A is the cross-sectional area of flow, and A_o is the cross-sectional area of the flow that is just sufficient to move the bed material, with no change in width, the effective part of the tractive force in moving bed material is $\gamma S(A-A_o)$. Also if the velocity of the tractive force is proportional to the mean velocity of flow, V, then the rate of work done by the effective part of the tractive force is $C_1 V\gamma S(A-A_o)$ or $C_1\gamma S(Q-Q_o)$. Since the bed load G_s is proportional to the work rate, G_s is equal to $C_1\gamma S(Q-Q_o)$. The constant C_1 is a function of slope and particle size. The final formula for unigranular material is:

$$G_s = \frac{86.7}{\sqrt{D}} S^{3/2}(Q - W q_o) \qquad (2)$$

in which

$$q_o = \frac{0.00532D}{S^{4/3}} \qquad (3)$$

where G_s = the bedload discharge, in pounds per second (lb/s);
D = the mean grain diameter, in inches (in.);
S = the energy gradient, in feet (ft) per ft;
Q = the water dischargn cubic feet per second (ft /s);
W = the width, in ft; and
q_o = the critical discharge, in ft^3/s per ft of width.

The formula is applied to mixtures (Schulits, 1935) by summing the computed bedload discharges for all size fractions; the discharge for each size fraction is computed using the mean diameter and the fraction of the sediment in the size fraction. Converting the equation for use with mixtures and changing the grain diameter from in. to ft and the bedload discharge from lb/s to lb/s per ft of width gives:

$$g_s = \sum_{i=1}^{n} i_b \frac{25}{\sqrt{D_{si}}} S^{3/2}(q - q_o) \qquad (4)$$

in which

$$q_o = \frac{0.0638 D_{si}}{S^{4/3}} \qquad (5)$$

where g_s = the bedload discharge, in lb/s per ft of width;
i_b = the fraction, by weight, of bed material in a given size fraction;
D_{si} = the mean grain diameter, in ft, of sediment in size fraction, i;
q = the water discharge, in ft^3/s per ft of width;
q_o = the critical discharge, in ft^3/s per ft of width, for sediment of diameter D_{si}; and
n = the number of size fractions in the bed-material mixture.

Kalinske Formula

The formula developed by Kalinske (1947) for computing bedload discharge of unigranular material is based on the continuity equation which states that the bedload discharge is equal to the product of the average velocity of the particles in motion, the weight of each particle, and the number of particles. The average particle velocity is related to the ratio of the critical shear (critical tractive force) to the total shear. The specific weight of a particle is a constant, and the number of particles in motion is related to the shear stress applied to the bed area. The formula can be applied to sand mixtures by summing the computed bedload discharge for all size fractions. For each fraction, the proportion of the bed subject to the shear is expressed as a function of the mean diameters and fractions, be weight, of all particles occupying the entire bed area subject to shear.

The formula is:

$$g_s = \sum_{i=1}^{n} V_* \gamma_s D_{si} P_i 7.3 \left[\frac{\bar{U}_g}{\bar{U}}\right] \quad (6)$$

in which

$$V_* = \frac{\sqrt{\tau_o}}{\rho} \quad (7)$$

$$\frac{\bar{U}_g}{\bar{U}} = f\left[\frac{\tau_{ci}}{\tau_o}\right] \quad (8)$$

$$\tau_{ci} = 12 D_{si} \quad (9)$$

$$P_i = \frac{0.35}{m}\left[\frac{i_b}{D_{si}}\right] \quad (10)$$

where g_s - the bedload discharge, in lb/s per ft of width;

n - the number of size fractions in the bed-material mixture;

V_* - the shear velocity, in feet per second (ft/s);

γ_s - the specific weight of the sediment in pounds per cubic foot (lb/ft^3);

D_{si} - the mean grain diameter, in ft, of sediment in size fraction, i;

P_i - the proportion of the bed area occupied by the particles in size fraction, i;

$\bar{U}_g$ - the average velocity, in ft/s, of particles in size fraction, i;

$\bar{U}$ - the mean velocity of flow, in ft/s, at the grain level;

τ_o - the total shear at the bed, in pounds per square foot (lb/ft^2), which equals $62.4dS$;

d - the mean depth, in ft;

S - the energy gradient, in ft per ft;

ρ - the density of water, in slugs per ft^3;

f denotes function of;

τ_{ci} - the critical tractive force, in lb/ft^2;

m - the summation of values of i_b/D_{si} for all size fractions in the bed-material mixture; and

i_b - the fraction, by weight, of bed material in a given size fraction.

Using the values of 165.36 for γ_s and 1.94 for ρ, the formula is:

$$g_s = 25.28 \sqrt{\tau_o} \sum_{i-1}^{n} \tau_{ci} \frac{\frac{i_b}{D_{si}}}{m} \left(\frac{\bar{U}_g}{\bar{U}}\right) . \qquad (11)$$

Values of $\bar{U}_g/\bar{U}$ are shown in Kalinske's (1947) figure 2 which expresses the relation between $\bar{U}_g/\bar{U}$ and τ_{ci}/τ_o for a value of $\sigma/\bar{U}$ equal to 1/4; where σ is the standard deviation of the instantaneous fluid velocity at the grain level about $\bar{U}$. The curve can be approximated by the following equation:

$$\text{Log} \frac{\bar{U}_g}{\bar{U}} = -0.068 - 1.1328 \left(\frac{\tau_{ci}}{\tau_o}\right) + 0.94 \left(\frac{\tau_{ci}}{\tau_o}\right)^2 - 1.206 \left(\frac{\tau_{ci}}{\tau_o}\right)^3 +$$

$$0.567 \left(\frac{\tau_{ci}}{\tau_o}\right)^4 - 0.0975 \left(\frac{\tau_{ci}}{\tau_o}\right)^5 . \qquad (12)$$

Meyer-Peter and Müller Formula

Meyer-Peter and Müller (1948) developed an empirical formula for the bedload discharge in natural streams. The original form of the formula in metric units for a rectangular channel is:

$$\gamma \frac{Q_s}{Q} \left(\frac{K_s}{K_r}\right)^{3/2} d\, S = 0.047\, \gamma_s'\, D_m + 0.25 \left(\frac{\gamma}{g}\right)^{1/3} g_s^{2/3} \qquad (13)$$

in which

$$D_m = \sum_{i-1}^{n} D_{si}\, i_b \qquad (14)$$

where γ - the specific weight of water and equals 1 metric ton per cubic meter (t/m^3);

Q_s - that part of the water discharge apportioned to the bed, in liters per second (l/s);

Q - the total water discharge, in l/s;

K_s - Strickler's (1923) coefficient of bed roughness, and is equal to one divided by Manning's roughness coefficient (n_s);

K_r - the coefficient of particle roughness, and is equal to $26/D_{90}^{1/6}$;

D_{90} - the particle size, in meters (m), for which 90 percent of the bed mixture is finer;

d - the mean depth, in m;

S - the energy gradient, in m per m;

γ'_s - the specific weight of sediment under water and equals 1.65 t/m^3 for quartz;

D_m - the effective diameter of bed-material mixture, in m;

g - the acceleration of gravity and equals 9.815 meters per second per second (m/s/s);

g_s - the bedload discharge measured under water, in metric tons per second (t/s) per per meter (m) of width;

n - the number of size fractions in the bed material;

D_{si} - the mean grain diameter, in m, of the sediment in size fraction, i; and

i_b - the fraction, by weight, of bed material in a given size fraction.

Converting the formula to English units gives:

$$g_s = \left[0.368 \frac{Q_s}{Q} \left(\frac{D_{90}^{1/6}}{n_s}\right)^{3/2} d\,S - 0.0698\, D_m\right]^{3/2} \qquad (15)$$

where g_s - the bedload discharge for dry weight, in lb/s per ft of width;

Q_s and Q are water discharges, in ft^3/s;

D_{90} and D_m are in mm;

d is in ft; and

n_s - Manning's roughness value for the bed of the stream.

For wide and smooth channels, the value of Q_s/Q is equal to 1, and the value of n_s is computed by the Manning equation converted to foot/pound units;

$$n_s = \frac{1.486\, d^{2/3}\, S^{1/2}}{V} \tag{16}$$

where V = the mean velocity, in ft/s.

Sheppard (1960) presented equations for evaluating Q_s/Q and n_s when the bank roughness must be considered.

For rectangular channel;

$$n_s = n_m\left[1 + \frac{2d}{W}\left\{1 - \left(\frac{n_w}{n_m}\right)^{3/2}\right\}\right]^{2/3} \tag{17}$$

and

$$\frac{Q_s}{Q} = \frac{1}{1 + \frac{2d}{W}\left(\frac{n_w}{n_s}\right)^{2/3}} \tag{18}$$

where n_w = the roughness value for the channel sides;

n_m = the roughness value for the total channel; and

W = the top width, in ft.

For trapezoidal channel;

$$n_s = n_m\left[1 + \frac{2d(1 + H^2)^{1/2}}{B}\left\{1 - \left(\frac{n_w}{n_m}\right)^{3/2}\right\}\right]^{2/3} \tag{19}$$

and

$$\frac{Q_s}{Q} = \frac{1}{1 + \frac{2d(1 + H^2)^{1/2}}{B}\left(\frac{n_w}{n_s}\right)^{2/3}} \tag{20}$$

in which

$$H = \frac{W - B}{2d} \tag{21}$$

where B is the bottom width, in ft; and

H is the channel side slope, in ft per ft.

The computer program computes the effective diameter of the bed-material mixture, D_m, from the entered sediment size-fraction data. However, the program does not compute the bedload discharge by size fractions.

Rottner Formula

Rottner (1959) developed an equation to express bedload discharge in terms of the flow parameters based on dimensional considerations and emperical coefficients. Using the data compiled by Johnson (1943), Rottner applied a regression analysis to determine the effect of a relative roughness parameter D_{50}/d. Rottner's equation is dimensionally homogeneous so that it can be presented directly in English units.

$$g_s = \gamma \left[(S_g-1)g\ d^3\right]^{1/2}\left\{\frac{V}{\sqrt{(S_g-1)g\ d}}\left[0.667\left(\frac{D_{50}}{d}\right)^{2/3} - 0.14\right] - 0.778\left(\frac{D_{50}}{d}\right)\right\} \quad (22)$$

where g_s = the bedload discharge, in lb/s per ft of width;
γ_s = the specific weight of sediment, in lb/ft^3;
S_g = the specific gravity of the sediment;
g = the acceleration of gravity, in feet per second per second (ft/s/s);
d = the mean depth, in ft;
V = the mean velocity, in ft/s; and
D_{50} = the particle size, in ft, at which 50 percent of the bed material by weight is finer.

In his derivation, wall and bed form effects were excluded, and Rottner stated that the equation may not be applicable when small quantities of bed material are being moved.

Einstein Bedload Formula

The bedload relation developed by Einstein (1950) is derived from the concept of probabilities of particle motion. A complete description of the complex procedure will not be presented here; however, the equations used in computing the bedload discharge are presented.

Einstein's method includes a trial-and-error procedure for computing the mean velocity, V, and splitting the hydraulic radius, R_b, into components pertaining to the effects of grain resistance, R_b', and the effects of channel bed-form resistance, R_b''. The computer program uses an equation presented by Einstein and Barbarossa (1952) in which R_b', in ft, is computed directly by

$$R_b' = \left[\frac{V\ (D_{65})^{1/6}}{7.66\ \sqrt{g\ S}}\right]^{3/2} \qquad (23)$$

where V = the measured mean velocity, in ft/s;

D_{65} = the particle size, in ft, at which 65 percent of the bed material by weight is finer;

g = the acceleration of gravity, in ft/s/s; and

S = the energy gradient, in ft per ft.

Then R_b is set equal to the mean depth, d, in ft; R_b'' is set equal to R_b minus R_b'; and the following variables are computed:

$$\delta' = 11.6\ \nu/U_*' \qquad (24)$$

where δ' = the laminar sublayer thickness, in ft, for U_*' ;

ν = the kinematic viscosity, in square ft^2/s; and

U_*' = the shear velocity, in ft/s, with respect to the grain.

in which

$$U_*' = \sqrt{R_b'\ S\ g} \qquad (25)$$

A dimensionless transition parameter (small x) is obtained from Einstein's (1950) figure 4 that shows the relationship between D_{65}/δ' and x. Subroutine FIG4 of the computer program uses a series of semilogarithmic equations to approximate Einsteins figure 4. Then Δ, the apparent roughness diameter, is set equal to D_{65}/x. Next the characteristic grain size of the mixture (capital X) is computed by:

$$X = 0.77\ \Delta \text{ if } \Delta/\delta' > 1.8 \text{ , or} \qquad (26)$$

$$X = 1.39\ \delta' \text{ if } \Delta/\delta' < 1.8 \qquad (27)$$

and a pressure correction, Y, due to the transition from smooth to rough conditions is obtained from Einstein's (1950) figure 8 that shows the relationship between D_{65}/δ' and Y. Subroutine FIG8 of the computer program uses a series of power functions to approximate Einstein's figure 8. Then the logarithm function (β_x) is computed by:

$$\beta_x = \log\ (10.6\ X/\Delta) \qquad (28)$$

The bedload discharge is computed for each size fraction in the bed-material mixture by first obtaining the "hiding factor" for grains in the bed mixture, ξ, from Einstein's (1950) figure 7 that shows the relationship between D_{si}/X and ξ where D_{si} is the grain diameter, in ft, of sediment in size fraction, i. Subroutine FIG7 of the computer program uses a series of power functions to approximate Einstein's figure 7. Then the adjusted intensity of shear on particles of a grain size fraction, ψ_*, is computed by:

$$\psi_* = \xi \, Y \left[\frac{1.025}{\beta_x}\right]^2 \psi \tag{29}$$

in which

$$\psi = \frac{1.65 \, D_{si}}{R'_b \, S} \tag{30}$$

where ψ = the intensity of shear on the particles of a size fraction. Next the intensity of transport for the individual grain size (ϕ_*) is obtained from Einstein's (1950) figure 10 that shows the relationship between ϕ_* and ψ_*. Subroutine FIG10 of the computer program uses a series of power functions to approximate Einsteins figure 10. Finally the bedload discharge for the size fraction, $i_B q_B$, in lb/s per ft of width, is computed from

$$i_B q_B = 1200 \, \phi_* \, (D_{si})^{3/2} \, i_b \, . \tag{31}$$

where i_b = the fraction, by weight, of bed material in a given size fraction.

The total bedload discharge, in lb/s per ft of width, is the sum of the bedload discharges from all size fractions.

Bed-Material Discharge Formulas

Eight bed-material formulas are presented in this section. Bed-material discharge is the discharge of sediment which is derived from and readily exchanges with the particles in the bed material; particles comprising the bed-material discharge move both as bedload and in suspension. Some investigators equate bed-material discharge to total-sediment discharge

even though it does not include the wash load (also called the fine-material load).

Laursen Formula

The equation developed by Laursen (1958) to compute the mean concentration of bed-material discharge is based on empirical relations:

$$\bar{C} = \sum_{i=1}^{n} i_b \left(\frac{D_{si}}{d}\right)^{7/6} \left(\frac{\tau'_o}{\tau_c} - 1\right) f\left(\frac{V_*}{\omega_i}\right) \tag{32}$$

in which

$$\tau'_o = \frac{\rho V^2}{58} \left(\frac{D_{50}}{d}\right)^{1/3} \tag{33}$$

$$\tau_c = Y_c \rho g (S_g - 1) D_{si} \tag{34}$$

where $\bar{C}$ - the concentration of bed-material discharge, in percent by weight;

n - the number of size fractions in the bed material;

i_b - the fraction, by weight, of bed material in a given size fraction;

D_{si} - the mean grain diameter, in ft, of the sediment in size fraction, i;

d - the mean depth, in ft;

τ'_o - Laursen's bed shear stress due to grain resistence;

τ_c - critical shear stress for particles of a size fraction;

f denotes function of;

V_* - the shear velocity, in ft/s;

ω_i - the fall velocity, in ft/s, of sediment particles of diameter D_{si};

ρ - the density of water, in slugs per ft^3;

V - the mean velocity, in ft/s;

D_{50} - the particle size, in ft, at which 50 percent of the bed material by weight is finer;

Y_c - a coefficient relating critical tractive force to sediment size;

g - acceleration of gravity, in ft/s/s; and

S_g - the specific gravity of sediment.

The density, ρ, has been introduced into the original τ'_o equation presented by Laursen so that the equation is dimensionally homogeneous, and Laursen's coefficient has been changed accordingly.

Substituting for τ'_o and τ'_c in equation 32 and converting $\overline{C}$ to C gives:

$$C = 10^4 \sum_{i=1}^{n} i_b \left[\frac{D_{si}}{d}\right]^{7/6} \left[\frac{V^2}{58\, Y_c\, D_{si}\, (S_g - 1)\, g} \left[\frac{D_{50}}{d}\right]^{1/3} - 1\right] f\left[\frac{V_*}{\omega_i}\right] \quad (35)$$

where C - the concentration of bed material-discharge, in parts per million by weight.

Values of $f(V_*/\omega_i)$ are shown in Laursen's (1958) figure 14, which expresses the relation between V_*/ω_i and $f(V_*/\omega_i)$. The computer program uses a series of equations to approximate Laursen's figure 14.

The value of Y_c was related by Laursen to D_{si}/δ as follows:

$$Y_c = 0.04 \quad \text{for} \quad \frac{D_{si}}{\delta} > 0.1 \quad (36)$$

$$Y_c = 0.08 \quad \text{for} \quad 0.1 > \frac{D_{si}}{\delta} > 0.03 \quad (37)$$

$$Y_c = 0.16 \quad \text{for} \quad 0.03 > \frac{D_{si}}{\delta} \quad (38)$$

in which δ - the thickness, in ft, of the laminar sublayer;

$$\delta = 11.6 \left[\frac{\nu}{V_*}\right] \quad (39)$$

where ν - kinematic viscosity, in square feet per second (ft^2/s).

Laursen's formula was developed using natural sediments with a specific gravity of 2.65, and medium diameters that ranged from 0.011 to 4.08 mm.

Engelund and Hansen Formula

Engelund and Hansen (1967) applied Bagnold's (1966) stream power concept and the similarity principle to derive the following sediment transport equation:

$$f'\phi = 0.1\,\theta^{5/2} \tag{40}$$

in which

$$f' = \frac{2\,g\,S\,d}{V^2} \tag{41}$$

$$\phi = \frac{g_s}{\gamma_s \sqrt{(S_g - 1)\,g\,D_{50}^3}} \tag{42}$$

$$\theta = \frac{d\,S}{(S_g - 1)\,D_{50}} \tag{43}$$

where f' = the friction factor;
ϕ = the dimensionless sediment discharge;
θ = a dimensionless shear parameter;
g = the acceleration of gravity, in ft/s/s;
S = the energy gradient, in ft per ft;
d = the mean depth, in ft;
V = the mean velocity, in ft/s;
g_s = the bed-material discharge, in lb/s per ft of width;
D_{50} = the particle size, in ft, at which 50 percent of the bed material by weight is finer;
S_g = the spcific gravity of the sediment; and
γ_s = the specific weight of sediment, in lb/ft^3.

Substituting for f', ϕ, and θ in the equation 40 gives:

$$g_s = \frac{0.05\,\gamma_s\,V^2\,d^{1/2}\,S^{3/2}}{D_{50}\,g\,(S_g - 1)^2} \tag{44}$$

The authors stated that the equation can be used with moderately sorted bed materials having mean fall diameters larger than 0.15 mm.

Colby Formula

Colby (1964) presented a graphical method to determine the discharge of sand size bed material that ranged from 0.1 to 0.8mm. Carl Nordin (U.S. Geological Survey, written commun., 1986) derived a series of equations to represent Colby's (1964) figure 24 and figure 26.

The bed-material discharge (g_s), in lb/s per ft of width, at a water temperature of 15.6 degrees Celsius (°C) (Colby's, 1964, figure 26) is

$$g_s = A\ (V - V_c)^B\ 0.672 \tag{45}$$

in which

$$V_c = 0.4673\ d^{0.1}\ D_{50}^{0.33} \tag{46}$$

where V = the mean velocity, in ft/s;
V_c = the critical velocity, in ft/s;
d = the mean depth, in ft;
D_{50} = the particle size, in mm, at which 50 percent of the bed material by weight is finer;
A = a coefficient; and
B = an exponent.

The value of the exponent B is equal to 2.5 when $(V - V_c)$ is less than 1. Otherwise it is computed by:

$$B = 1.453\ D_{50}^{(-0.138)} \tag{47}$$

The value of the coefficient A is determined by the following series of power equations based on mean depth for 5 values of D_{50}:

For D_{50} of 0.1 mm $\quad A = 1.453\ d^{0.61}$ (48)

For D_{50} of 0.2 mm $\quad A = 1.329\ d^{0.48}$ (49)

For D_{50} of 0.3 mm $\quad A = 1.4\ d^{0.3}$ (50)

For D_{50} of 0.4 mm $A = 1.26\ d^{0.3}$, and (51)

For D_{50} of 0.8 mm $A = 1.099\ d^{0.3}$. (52)

Colby's (1964) figure 24 presents two adjustment coefficients, AF and CF, for determinining the bed-material discharge for temperatures other than 15.6 °C. The computer program uses a series of equations to approximate Colby's curves of depth compared to AF for water temperatures of 0, 5, 10, 20, 30, and 40 °C. AF is equal to 1 for a water temperature of 15.6 °C. The value of AF for intermediate temperatures are determined by interpolation. Colby's curve of D_{50} compared to CF gives the following values of CF:

For D_{50} of 0.1 mm $CF = 0.64$ (53)

For D_{50} of 0.2 mm $CF = 1$ (54)

For D_{50} of 0.3 mm $CF = 1$ (55)

For D_{50} of 0.4 mm $CF = 0.88$, and (56)

For D_{50} of 0.8 mm $CF = 0.2$. (57)

Applying the two coefficients, the equation to compute g_s for the five D_{50} values becomes:

$$g_s = A\ (V - V_c)^B\ [1 + (AF - 1)\ CF]\ 0.672\ . \quad (58)$$

The value of g_s for intermediate D_{50} values are determined by logarithmic interpolation.

Ackers and White Formula

Ackers and White (1973) developed a general sediment-discharge function in terms of three dimensionless groups; D_{gr} (size), F_{gr} (mobility), and G_{gr} (discharge). The dimensionless grain diameter D_{gr} is expressed as:

$$D_{gr} = D_{50} \left[\frac{g\,(S_g - 1)}{\nu^2} \right]^{1/3} \qquad (59)$$

where D_{50} = the particle size, in ft, at which 50 percent of the bed material by weight is finer;

g = the acceleration of gravity, in ft/s/s;

S_g = the specific gravity of the sediment; and

ν = the kinematic viscosity, in ft^2/s.

Ackers and White considered that coarse sediments are transported mainly as bedload, and only a part of the shear stress on the channel bed is effective in causing the movement of coarse sediments, even though fine sediments are considered to be tranported as suspended load, and the total shear stress is effective in causing the movement of the fine sediments. They defined a dimensionless mobility number, F_{gr}, as:

$$F_{gr} = \frac{V_*^n}{\sqrt{g\,D_{50}\,(S_g - 1)}} \left[\frac{V}{\sqrt{32}\,\log\left(\frac{\alpha\,d}{D_{50}}\right)} \right]^{1-n} \qquad (60)$$

where d = the mean depth, in ft;

V_* = the shear velocity, in ft/s;

V = the mean velocity, in ft/s;

α = the coefficient in the rough turbulent equation with a value of 10; and

n = the transition exponent depending on sediment size.

Then they developed the following dimensionless expression for general sediment transport, G_{gr}, based on Bagnold's (1966) stream power concept:

$$G_{gr} = \frac{X\,d}{S_g\,D_{50}} \left(\frac{V_*}{V} \right)^n \qquad (61)$$

where X is the sediment-discharge concentration expressed as the mass flux per unit of mass flow rate. Transposing the equation to solve for X, and converting X to C gives:

$$C = 10^6 \frac{G_{gr} S_g D_{50} \left[\frac{V}{V_*}\right]^n}{d} \quad (62)$$

where C = the concentration of bed-material discharge, in parts per million by weight.

Using flume data from other investigators, Ackers and White developed a new general transport function, G_{gr}, and evaluated the associated coefficients. The equation is:

$$G_{gr} = C_A \left[\frac{F_{gr}}{A} - 1\right]^m \quad (63)$$

where A = the value of the Froude number at nominal initial motion;
m = the exponent in the sediment transport function; and
C_A = the coefficient in the sediment transport function.

The values of n, A, m and C_A were evaluated for two size ranges of bed material. The values for the intermediate size range, $D_{gr} = 1$ (0.04 mm silt size) to $D_{gr} = 60$ (2.5 mm sand size) were ;

$$n = 1.00 - 0.56 \log D_{gr} , \quad (64)$$

$$A = \frac{0.23}{\sqrt{D_{gr}}} + 0.14 , \quad (65)$$

$$m = \frac{9.66}{D_{gr}} + 1.34 , \text{ and} \quad (66)$$

$$\log C_A = 2.86 \log D_{gr} - (\log D_{gr})^2 - 3.53 . \quad (67)$$

The values for the coarse size range with D_{gr} greater than 60 were:

$$n = 0.00 , \quad (68)$$

$$A = 0.17 , \quad (69)$$

$$m = 1.5 , \text{ and} \quad (70)$$

$$C_A = 0.025 . \quad (71)$$

Fine size material with D_{gr} less than 1 exhibit cohesive properties and conventional sediment transport equations do not apply.

Ackers and White suggested that D_{35}; the particle size, in ft, at which 35 percent of the bed material by weight is finer; be used in place of D_{50} for graded and coarse sediments.

The following procedure is used to calculate the concentration of bed-material discharge:

1. The value of D_{gr} is computed using equation 59.
2. Values of A, C_A, n, and m associated with the computed D_{gr} value are determined using either equations 64-67 or 68-71.
3. The value of the particle mobility, F_{gr}, is computed using equation 60.
4. The value of G_{gr} is computed using equation 63.
5. The bed-material discharge concentration, C, is computed using equation 62.

Yang Sand Formula

Yang (1973) derived an equation to compute concentration of the bed-material discharge, for sand bed streams, based on dimensional analysis and the concept of unit stream power. He defined unit stream power as the rate of potential energy dissipated per unit weight of water, which is expressed by the velocity and slope product, VS. Yang and Molinas (1982) showed that the basic form of the unit stream power equation can also be derived from well-established theories in fluid mechanics and turbulence. Yang's dimensionless unit stream power equation is:

$$\log C = 5.435 - 0.286 \log \frac{\omega D_{50}}{\nu} - 0.457 \log \frac{V_*}{\omega} + \left(1.799 - 0.409 \log \frac{\omega D_{50}}{\nu} - 0.314 \log \frac{V_*}{\omega}\right) \log \left(\frac{V S}{\omega} - \frac{V_{cr} S}{\omega}\right) \quad (72)$$

in which the dimensionless critical velocity at incipient motion can be expressed as:

$$\frac{V_{cr}}{\omega} = \frac{2.5}{\log \frac{V_* D_{50}}{\nu} - 0.06} + 0.66 \quad \text{for} \quad 1.2 < \frac{V_* D_{50}}{\nu} < 70 \qquad (73)$$

and

$$\frac{V_{cr}}{\omega} = 2.05 \quad \text{for} \quad 70 \leq \frac{V_* D_{50}}{\nu} \qquad (74)$$

where C = the concentration of bed-material discharge, in parts per million by weight;

ω = the average fall velocity, in ft/s, of sediment particles of diameter D_{50};

D_{50} = the particle size, in ft, at which 50 percent of the bed material by weight is finer;

ν = the kinematic viscosity, in ft^2/s;

V_* = the shear velocity, in ft/s;

V = the average velocity, in ft/s;

S = the energy slope, in ft/ft; and

V_{cr} = the average flow velocity, in ft/s, at incipient motion.

Coefficients for the equation were determined by multiple regression analysis of 463 sets of laboratory data on flow and sediment parameters associated with discharge of bed materials consisting of sand that had a median sieve diameter that ranged from 0.015 to 1.71 mm. The term VS/ω is the dimensionless unit stream power. The lower boundary of 1.2 in equation 73 for $V_* D_{50}/\nu$ is based on the minimum values of data used in the calibration of coefficients. This limit prevents the value of V_{cr}/ω from going to infinity. The fall velocities of the sediment particles are determined from Figure 2 presented in the U.S. Inter-Agency Committee on Water Resources, Subcommittee on Sedimentation (1957).

Moore and Burch (1986) applied the unit stream power theory to the study of sediment transport in sheet and rill flows. They found that Yang's (1973) equation can accurately predict sediment discharge in the sand size range provided that a constant critical dimensionless velocity at incipient motion is used in place of equation 73 or 74. They further showed that good agreement between the computed and measured results of clay discharge in rills when the effective aggregate diameters were used in the equation.

The procedure is suitable for computing the discharge of graded material. The concentration is computed for each size fraction by using the mean diameter and fall velocity in the size fraction. Then the total bed-material discharge concentration for the graded material is obtained from:

$$C = \sum_{i=1}^{n} i_b C_i \qquad (75)$$

where n = the number of size fractions in the bed material;

i_b = the fraction, by weight, of bed material in a given size fraction; and

C_i = the computed concentration in the size fraction, i.

Yang Gravel Formula

Yang (1984), using the same dimensional analysis and multiple regression methods as was used to derive discharge rates in sand bed streams (Yang, 1973), derived an equation to compute the bed-material discharge concentration, in gravel bed streams. The same definition of unit stream power is used in both the sand and gravel transport equations. Yang's dimensionless unit stream power equation for gravel transport is:

$$\log C = 6.681 - 0.633 \log \frac{\omega D_{50}}{\nu} - 4.816 \log \frac{V_*}{\omega} +$$

$$\left(2.784 - 0.305 \log \frac{\omega D_{50}}{\nu} - 0.282 \log \frac{V_*}{\omega}\right) \log \left(\frac{V S}{\omega} - \frac{V_{cr} S}{\omega}\right) \qquad (76)$$

in which the dimensionless critical velocity at incipient motion is the same as that for sand transport; namely:

$$\frac{V_{cr}}{\omega} = \frac{2.5}{\log \frac{V_* D_{50}}{\nu} - 0.06} + 0.66 \quad \text{for} \quad 1.2 < \frac{V_* D_{50}}{\nu} < 70 \qquad (77)$$

and

$$\frac{V_{cr}}{\omega} = 2.05 \quad \text{for} \quad 70 \leq \frac{V_* D_{50}}{\nu} \qquad (78)$$

where C = the concentration of bed material discharge, in parts per million by weight;

ω - the average fall velocity, in ft/s, of sediment particles of diameter D_{50};

D_{50} - the particle size, in ft, at which 50 percent of the bed material by weight is finer;

ν - the kinematic viscosity, in ft^2/s;

V_* - the shear velocity, in ft/s;

V - the average velocity, in ft/s;

S - the energy slope, in ft per ft; and

V_{cr} - the average flow velocity, in ft/s, at incipient motion.

Coefficients for the equation were determined by multiple regression analysis of 166 sets of laboratory data on flow and sediment paramters associated with discharge of bed materials consisting of gravel that had a median sieve diameter that ranged from 2.46 to 7.01 mm. The fall velocities of the sediment particles are determined from Figure 2 presented in the U.S. Inter- Agency Committee on Water Resources, Subcommittee on Sedimentation (1957). Figure 2 can be used to determine velocities of particles as large as 10 mm in diameter. The fall velocity of the sediment particles larger 10 mm are computed by the equation developed by Rubey (1933).

Similar to the method for graded-sand transport, the concentration of gravel bed-material discharges is computed for each size fraction by using the mean diameter and fall velocity of the size fraction. Then the total bed-material discharge concentration, C, for the graded material is obtained from:

$$C = \sum_{i=1}^{n} i_b \, C_i \qquad (79)$$

where n - the number of size fractions in the bed material;

i_b - the fraction, by weight, of bed material in a given size fraction;

C_i - the computed concentration in the size fraction, i.

Einstein Formula

Einstein (1950) presented a method to combine his computed bedload discharge with a computed suspended bed-material discharge to yield the total bed-material discharge. A complete description of the procedure will not be presented; however, the equations used in computing the suspended bed-material discharge are presented. The computation of $i_B q_B$ values and other variables defined in the section "Einstein Bedload Formula" (page 11) are not redefined here.

First, a parameter of total transport, P, is computed by:

$$P = 2.3026 \log \frac{30.2 \times R_b}{D_{65}} \quad . \tag{80}$$

Then the suspended bed-material discharge is computed for each size fraction by integrating the product of the flow velocity and the suspended-sediment concentration from the surface down to the bed layer, A, which is a dimensionless distance defined by:

$$A = 2 D_{si} / R_b . \tag{81}$$

The velocity distribution is defined from Keulegan's (1938) equation and the suspended-sediment concentration distribution is given by:

$$C_y = C_a \left[\frac{d - y}{y} \quad \frac{a}{d - a} \right]^Z \tag{82}$$

where C_y and C_a are the concentration at points y and a above the bed, in parts per million by weight;

d - the total depth, in ft; and

Z - the exponent of suspended-sediment distribution.

in which

$$Z = \frac{\omega_i}{0.4 V'_*} \tag{83}$$

where ω_i is the fall velocity, in ft/s, of sediment particles of diameter D_{si}.

Values of Einstein's suspended-sediment discharge integrals I_1 and I_2 are computed with subroutine POWER of the computer program using calculated values A and Z. Subroutine POWER first evaluates the Einstein J_1 and J_2 integral functions by a procedure developed by Li (1974). The method is based on expanding the integral functions in the form of a power series. The J values then are converted to I values by multiplying them by FACT; where

$$FACT = 0.216 \frac{A^Z - 1}{(1 - A)^Z} \quad . \tag{84}$$

The total bed-material discharge for the size fraction, $i_T q_T$, in lb/s per ft of width is then computed from:

$$i_T q_T = i_B q_B \, (PI_1 + I_2 + 1) \quad . \tag{85}$$

The total bed-material discharge, in lb/s per ft of width, is the sum of the bed-material discharges from all size fractions.

Toffaleti Formula

The procedure to determine bed-material discharge developed by Toffaleti (1968) is based on the concepts of Einstein (1950) with three modifications: (1) velocity distribution in the vertical is obtained from an expression different from that used by Einstein; (2) several of Einstein's correction factors are adjusted and combined; and (3) the height of the zone of bedload transport is changed from Einstein's two grain diameters. Toffaleti defines his bed-material discharge as total river sand discharge even though he defines the range of bed-size material from 0.062 to 16 mm.

Toffaleti presented his procedure by the following series of equations and definitions:
Computation is initiated by evaluating the following variables which are common to all size fractions:

$$Z_v = 0.1198 + 0.00048 \, TDF \tag{86}$$

where Z_v = the exponent of velocity distribution; and

TDF = the water temperature, in degrees Fahrenheit (°F). The computer program converts the entered temperature, in °C.

$$SI = S\ d\ C_z \tag{87}$$

in which

$$C_z = 260.67 - 0.667\ TDF \tag{88}$$

where SI = a variable used in the later evaluation of ZOM, the exponent of suspended-sediment concentration distribution in the middle zone;

S = the energy gradient, in ft per ft;

d = the mean depth, in ft; and

C_z = a temperature related parameter used in evaluating ZOM.

$$YA = d/11.24 \tag{89}$$

where YA = the distance, in ft, from the bed to the upper limit of the lower zone.

$$YB = d/2.5 \tag{90}$$

where YB = the distance, in ft, from the bed to the upper limit of the middle zone.

$$C_v = 1 + Z_v \tag{91}$$

where C_v = a velocity distribution parameter.

$$U2 = \frac{V}{\sqrt{g\ D_{65}\ S}} \tag{92}$$

where U2 = a parameter for evaluating U'_*, the shear velocity with respect to the grain;

V = mean velocity, in ft/s;

g = the acceleration of gravity, in ft/s/s; and

D_{65} - the particle size, in ft, at which 65 percent of the bed material by weight is finer.

$$U3 = \frac{V^3}{g\ \nu\ S} \tag{93}$$

where U3 - a parameter for evaluating U'_*; and

ν - the kinematic viscosity, in ft^2/s.

U1, a parameter for evaluating U''_*, is related to V and U'_*, and is obtained from Toffaleti's (1968) figure 3 which shows the relationship between U2 and U3 and U1. The computer program evaluates U1 by a series of semilogarithmic equations to approximate Toffaleti's figure 3. Then:

$$U'_* = V/U1 \tag{94}$$

A correction factor, A, replaces Einstein's (1950) ξ, Y, and θ, and is evaluated by computing PAM:

$$PAM = P^{1/3}/AM \tag{95}$$

in which

$$P = 10^5\nu, \text{ and} \tag{96}$$

$$AM = 10\ U'_* \ . \tag{97}$$

Then the value of A is obtained from Toffaleti's (1968) figure 4 that shows the relationship between PAM and A. The computer program uses a series of power functions to approximate Toffaleti's figure 4. Lastly, T, a parameter that includes the constants and those components of the shear force that are a function of water temperatures, is computed by;

$$T = (0.051 + 0.00009\ TDF)\ 1.1 \ . \tag{98}$$

The bedload discharge, GBL, and bed-material discharge, GT, in tons per day, are computed for each size fraction. Bed-material discharge is the sum of the discharges from the three zones: (1) lower zone, GA, from 0 to YA feet, (2) middle zone, GB, from YA to YB feet, and (3) upper zone, GC, from YB to d feet. First, the value of GF, the discharge, in t/d per ft

of width, moving in the vertical section between levels from 2 times the grain diameter, DD, to YA, and with the assumption that the bed is composed entirely of one size fraction, is computed. GF for the first size fraction (0.00029 feet) is

$$GF = \frac{1.905}{\left[\frac{T\,A}{V^2}\right]^{5/3}} \text{ ; and} \tag{99}$$

GF for each succeeding coarser size fraction is reduced by division by $2^{5/3}$ or 3.175. The exponents in the point-discharge equations for the lower, middle, and upper zones (F1, F2, and F3), and the exponents in the integrated discharge equations for the lower, middle, and upper zones (F4, F5, and F6) are computed by:

$$ZOM = \frac{\omega_i\, V}{SI} \tag{100}$$

where ω_i = the fall velocity, in ft/s, of sediment particles of mean size D_{si}; and

D_{si} = the mean grain diameter, in ft, of the sediment in size fraction i.

The fall velocities of the sediment particles are determined from Figure 2 presented in the U.S. Inter-Agency Committee on Water Resources, Subcommittee on Sedimentation (1957). If the computed value of ZOM is greater than 1.5 Z_v, ZOM is set equal to 1.5 Z_v. The F1 to F6 values are then computed by:

$$F1 = 0.756\ ZOM - Z_v \tag{101}$$

$$F2 = ZOM - Z_v \tag{102}$$

$$F3 = 1.5\ ZOM - Z_v \tag{103}$$

$$F4 = 1 - F1 \tag{104}$$

$$F5 = 1 - F2\ \text{, and} \tag{105}$$

$$F6 = 1 - F3\ . \tag{106}$$

Next the bedload discharge concentration, C, is computed by;

$$C = i_b \, W \, X \tag{107}$$

in which

$$X = \frac{F4 \; GF}{YA^{F4} - DD^{F4}} \quad , \text{ and} \tag{108}$$

$$DD = 2 \, D_{si} \tag{109}$$

where i_b = the fraction, by weight, of bed material in a given size range; and

W = the width, in ft.

Bedload discharge, GBL, in t/d, for the sand fraction is:

$$GBL = C \, DD^{F4} \quad . \tag{110}$$

The concentration of the discharge in the bed-load layer (UBL), in lb/ft^3, assuming a bed composed entirely of the size fraction being considered, is computed as

$$UD = C_v \, V \left(\frac{DD}{d}\right)^{Z_v} \quad , \text{ and} \tag{111}$$

$$UBL = \frac{X \; DD^{F4}}{43.2 \; UD \; DD} \quad . \tag{112}$$

If the computed value of UBL is greater than 100, the bedload discharge is multiplied by 100/UBL. Bed-material discharges for the three zones are computed by:

$$GA = \frac{C}{F4} \left(YA^{F4} - DD^{F4}\right) + GBL \tag{113}$$

$$GB = \frac{C}{F5} \, YA^{(F2 - F1)} \left(YB^{F5} - YA^{F5}\right) \quad , \text{ and} \tag{114}$$

$$GC = \frac{C}{F6} \, YA^{(F2 - F1)} \, YB^{(F3 - F2)} \left(d^{F6} - YB^{F6}\right) \quad . \tag{115}$$

Then the total bed-material discharge, GT, for the size fraction is the sum of GA, GB, and GC.

The total bedload discharge, in t/d, is the sum of the GBL's for all size fractions; and the bed-material discharge, in t/d, is the sum of the GT's for all size fractions.

EVALUATION OF SEDIMENT-DISCHARGE FORMULAS

Investigators need to select a reliable sediment-discharge formula. Selection may be complicated because computed results from different formulas may differ drastically from each other and from actual measurements. The potential accuracy of a formula or procedure may be judged from the general assumptions and theoretical basis used to develope the method, from the similarity between the experimental conditions used to develop parameters and relation of the method to real field conditions, and from direct comparison with field measurements. The previous section, "Description of fluvial sediment-discharge formulas", presented the general assumptions used and theoretical basis of the 13 formulas presented in this report. Comparisons by different investigators of computed and measured results for these 13 sediment discharge formulas are given in this section to assist in the selection of a formula. The discrepancy ratio, defined as the ratio between computed and measured sediment discharges, is used as an indicator of the accuracy of a formula.

Schulits and Hill (1968) made comparisons of sediment discharges computed from 14 bedload transport formulas and sediment discharges measured in flumes and rivers. Of the five bedload formulas presented in this report, they recomended the Schoklitsch (1934) formula and the Meyer-Peter and Müller (1948) formula.

White, Milli and Crabbe (1975, 1978) made detailed comparisons of discharges computed from sediment discharge formulas and measured discharges from 1,270 flume experiments and field surveys. The median particle size of the bed material present in measurements ranged from 0.04 to 4.94 mm. The formulas were divided into groups according to their general performance. Results of nine of the formulas that are presented in this report were:

A. Formulas with about 60 or more percent of the computed discrepancy ratios in the range 1/2 to 2 with little scatter within the sets.

Ackers and White (1973)
Engelund and Hansen (1967)
Rottner (1959)

B. Formulas with 35 to 50 percent of the computed discrepancy ratios in the range 1/2 to 2 with little scatter within the sets.

Einstein bedload (1950)
Einstein (1950)
Toffaleti (1968)

C. Formulas with 35 to 50 percent of the computed discrepancy ratios in the range 1/2 to 2 but with substantial scatter within the data sets.

Laursen (1958)

D. All other formulas.

Kalinske (1947)
Meyer-Peter and Müller (1948)

White, Milli, and Crabbe (1975, 1978) rated the Ackers and White (1973) formula as the most reliable formula.

In Yang's (1976) discussion of the comparisons made by White, Milli, and Crabbe (1975), Yang used 1,247 field and laboratory measurements which essentially duplicated the set used by White, Milli, and Crabbe (1975). Ninety-one percent of the discrepancy ratios of discharges computed with Yang's (1973) formula and measured discharges ranged from 1/2 to 2. Yang's comparisons seems to be consistent with the verifications made by Alonso (1980), American Society of Civil Engineers (1982), and Yang and Molinas (1982).

Alonso (1980) compared discharges computed with eight sediment-discharge formulas with discharges measured during 40 field surveys and 225 flume experiments. The data used by Alonso were collected with special facilities so that total bed-material discharges were measured accurately. Consequently, there is no uncertainty on the amount of unmeasured discharge near the river bed. The median particle size of the bed material in the measurements ranged from 0.10 to 1.35 mm. Results for five of the formulas presented in this report are given in table 2. The Yang (1973) formula was the most reliable for the entire range of flow conditions and gave consistent discrepancy ratios. Both Ackers and White (1973) and

Table 2.--Statistical summary of discrepancy ratios of five sediment-discharge formulas[1]

Author of formula	Number of tests	Discrepancy ratio[2]				Percentage of tests with ratio ranging 1/2 to 2
		Mean	95%-confidence limits of the mean		Standard deviation	
Field data						
Ackers and White (1973)	40	1.27	1.05	1.48	0.68	87.8
Engelund and Hansen (1967)	40	1.46	1.28	1.64	0.56	82.9
Laursen (1958)	40	0.65	0.49	0.80	0.48	56.1
Yang (1973)	40	1.01	0.89	1.13	0.39	92.7
Meyer-Peter and Müller (1948)	40	0.24	0.22	0.27	0.09	0
[3]**Flume data with d/D > 70**						
Ackers and White (1973)	177	1.34	1.24	1.54	1.29	73.0
Engelund and Hansen (1967)	177	0.73	0.63	0.83	0.68	51.1
Laursen (1958)	177	0.81	0.73	0.88	.51	71.4
Yang (1973)	177	0.99	0.93	1.08	0.60	79.8
Meyer-Peter and Müller (1948)	177	0.40	0.39	0.47	0.49	18.5
[4]**Flume data with d/D < 70**						
Ackers and White (1973)	48	1.12	0.93	1.28	0.52	89.6
Engelund and Hansen (1967)	48	0.75	0.59	0.90	0.50	66.7
Laursen (1958)	48	1.04	0.76	1.32	0.99	79.2
Yang (1973)	48	0.90	0.79	1.05	0.51	85.4
Meyer-Peter and Müller (1948)	48	1.03	1.00	1.27	0.83	72.9

[1] Modified from Alonso, 1980, p. 431.

[2] Ratio between computed and measured sediment discharges.

[3] Ratio between mean depth (d), in ft, and sediment diameter (D), in ft.

[4] Shallow flow where surface wave-effect becomes significant. Most sediment transport formulas do not account for interaction with the surface waves.

Engelund and Hansen (1967) formulas produced reasonable values of discrepancy ratios. Alonso included the bedload-discharge formula of Meyer-Peter and Müller in table 2 even though the others are bed-material discharge formulas.

The American Society of Civil Engineers Task Committee on Relations Between Morphology of Small Streams and Sediment Yield (1982) endorsed the work of Alonso (1980) and ranked the accuracy of the eight formulas evaluated by Alonso. Their ranking of five of the formulas presented in this report was:

1. Yang (1973)
2. Laursen (1958)
3. Ackers and White (1973)
4. Engelund and Hansen (1967)
5. Meyer-Peter and Müller (1948)

Yang and Molinas (1982) made detailed comparisons of computed discharges from seven sediment discharge formulas and measured discharges from 1,259 sets of flume experiments and field surveys. The median particle size of the bed material in these measurements varied from 0.15 to 1.71 mm. Results of comparisons for four of the formulas that were presented in this report are given in table 3. Yang's (1973) formula gave discharges that compared best with discharges from the laboratory experiments and field surveys. Colby's (1964) formula gave the least accurate results for the shallow flow conditions in the laboratory.

Brownlie (1981) made detailed comparisons, based on data from about 1000 flume experiments and field observations, of computed discharges from 13 sediment bedload discharge and bed-material discharge formulas and measured discharges. The median particle size of the bed material in the data ranged from 0.086 to 1.44 mm. Results of seven of the formulas presented in this report are given in table 4. A parameter that is log-normally distributed can be described by its geometric mean and geometric standard deviation. The geometric mean and geometric standard deviation were calculated by taking the antilogs of the mean and standard deviation respectively, of the logarithms of ratios of computed to observed discharge concentrations. For the ratio of calculated to observed concentration, geometric mean and geometric standard deviation values of 1 would indicate

Table 3.--Summary of comparisons of accuracies of four bed-material discharge formulas[1]

Author of formula	Discrepancy ratio[2]					Number of tests
	Mean	Percent of data in range of variation			Standard deviation	
		0.75-1.25	0.5-1.5	0.25-1.75	0.5-2.0	
Laboratory data						
Colby (1964)	0.31	4	10	29	10	0.64	865
Yang (1973)	1.01	55	85	95	92	0.44	1093
Engelund and Hansen (1967)	0.88	26	59	91	65	0.72	1093
Ackers and White (1973)	1.28	37	68	84	86	0.69	1093
River data[3]						
Colby (1964)	0.61	13	29	71	33	0.66	102
Yang (1973)	1.13	48	77	92	90	0.43	166
Engelund and Hansen (1967)	1.51	34	58	72	79	0.75	166
Ackers and White (1973)	1.50	31	61	75	80	0.80	166
All data						
Colby (1964)	0.34	5	12	33	12	0.64	967
Yang (1973)	1.03	54	84	95	92	0.44	1259
Engelund and Hansen (1967)	0.96	27	59	88	67	0.72	1259
Ackers and White (1973)	1.31	36	67	83	85	0.71	1259

[1] Modified from Yang and Molinas, 1982, p. 785.

[2] Ratio between computed and measured sediment concentration.

[3] The discrepancy ratio for most river data should be greater than 1.0 because part of the suspended bed-material discharge is in the unmeasured zone.

Table 4.--Geometric mean and geometric standard deviation of the ratios of computed to observed concentrations from seven sediment discharge formulas, for laboratory experiments and field observations[1]

[Mean: Geometric mean. S.D.: Geometric standard deviation.

Author of formula	Number of tests	Laboratory		Field	
		Mean	S.D.	Mean	S.D.
Ackers and White (1973)	998	1.150	1.758	0.694	2.027
Einstein (1950)	950	0.628	4.059	0.420	3.719
Engelund and Hansen (1967)	999	1.236	2.064	0.916	1.997
Laursen (1958)	972	1.296	2.532	0.420	3.098
Rottner (1959)	999	0.920	2.101	0.603	1.904
Toffaleti (1968)	995	1.166	2.749	0.854	2.572
Yang (1973)	993	1.215	1.710	0.471	3.077

[1] Modified from Brownlie, 1981, p. 188.

perfect agreement. The geometric standard deviation will be greater than or less than 1, depending on whether the formula tends to over-predict or under-predict. The Ackers and White (1973) and the Engelund and Hansen (1967) formulas gave the most satisfactory geometric standard deviation for combined laboratory experiments and field observations.

Yang (1984) compared concentrations computed from four sediment discharge formulas and measured gravel concentrations. The median particle size of the bed material in 167 data sets ranged from 2.46 to 7.01 mm. The results are given in table 5. Concentrations computed by the Meyer-Peter and Müller (1948) formula for the 35 observations by Casey (Johnson, 1943) showed poor correlation with measured concentrations.

Comparisons of bed-material discharges computed by seven formulas presented in this report and observed bed-material discharge from the Niobrara River near Cody, Nebraska, (Colby and Hembree, 1955) are shown in figure 1. Comparisons of bedload discharges computed by five formulas presented in this report are shown in figure 2. The median particle size of the bed material in the Niobrara River data was 0.28 mm. Similar comparisons of data from Mountain Creek (Einstein, 1944) are shown in figures 3 and 4.

Table 5.--Summary of comparisons of accuracies of four gravel transport formulas[1]

Author of formula	Discrepancy ratio[2]				Correlation coefficient	Standard deviation	Mean error in percent
	Mean	Percent of data in range					
		0.75-1.25	0.5-1.5	0.25-1.75			
Yang (1984)	1.05	47	75	92	0.92	0.51	5
Engelund and Hansen (1967)	0.85	13	40	86	0.93	0.99	-15
Ackers and White (1973)	1.21	44	76	83	0.93	0.89	21
Meyer-Peter and Müller (1948)	1.86	61	81	87	0.91	8.98	86

[1] Modified from Yang, 1984, p. 1789-90.

[2] Ratio between computed and measured concentration.

The median particle size of the Mountain Creek bed material was 0.90 mm. A summary of the accuracies of the four comparisons are given in table 6. Computed results of Yang (1973), Ackers and White (1973) and Toffaletti (1968) bed-material formulas agree most closely with the Niobrara observations; and results of Yang (1973), Engelund and Hansen (1967) and Ackers and White (1973) bed-material formulas agree most closely with the Mountain Creek observations. Because the D_{50} value of the Mountain Creek data is at the upper limit of the Colby formula, the formula computed values were extremely low. In figure 2 the computed results from different bedload formulas are less than the observed Niobrara bed-material discharges as expected. However, figure 4 shows that computed results from the bedload formulas proposed by Kalinske, Einstein, and Rottner are greater than the observed Mountain Creek bed-material discharges, which indicates an over estimation of the bedload discharge.

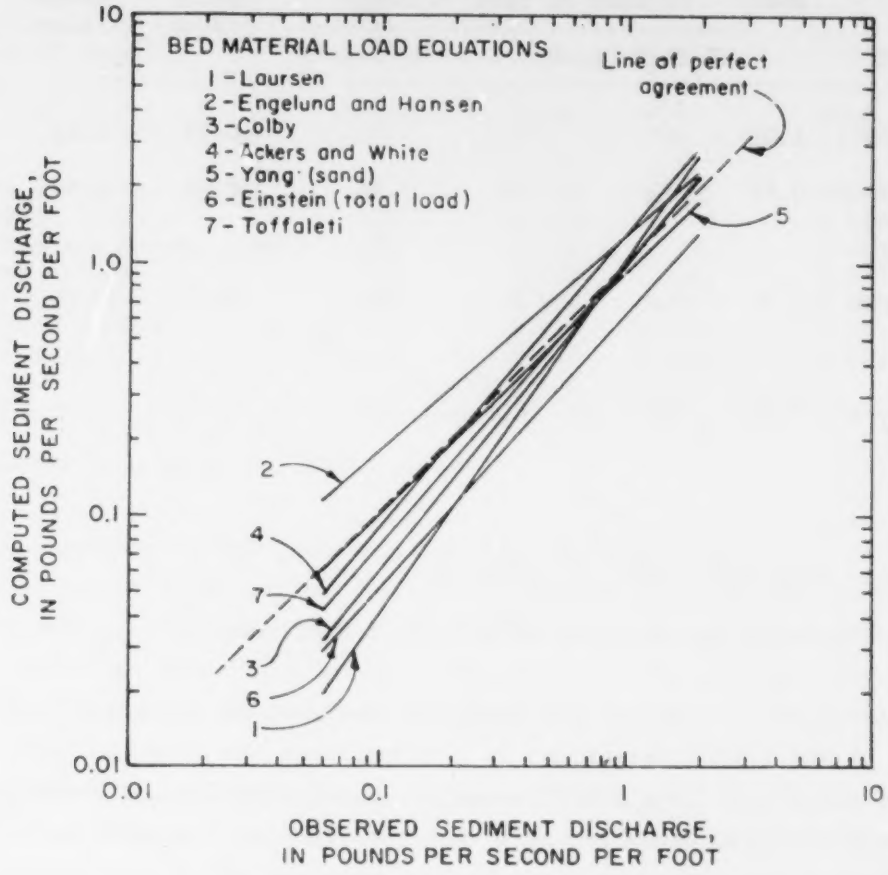

Figure 1.-- Comparison of bed-material discharges computed by seven formulas presented in this report to observed bed-material discharge, Niobrara River near Cody, Nebraska (Data from Colby and Hembree, 1955)

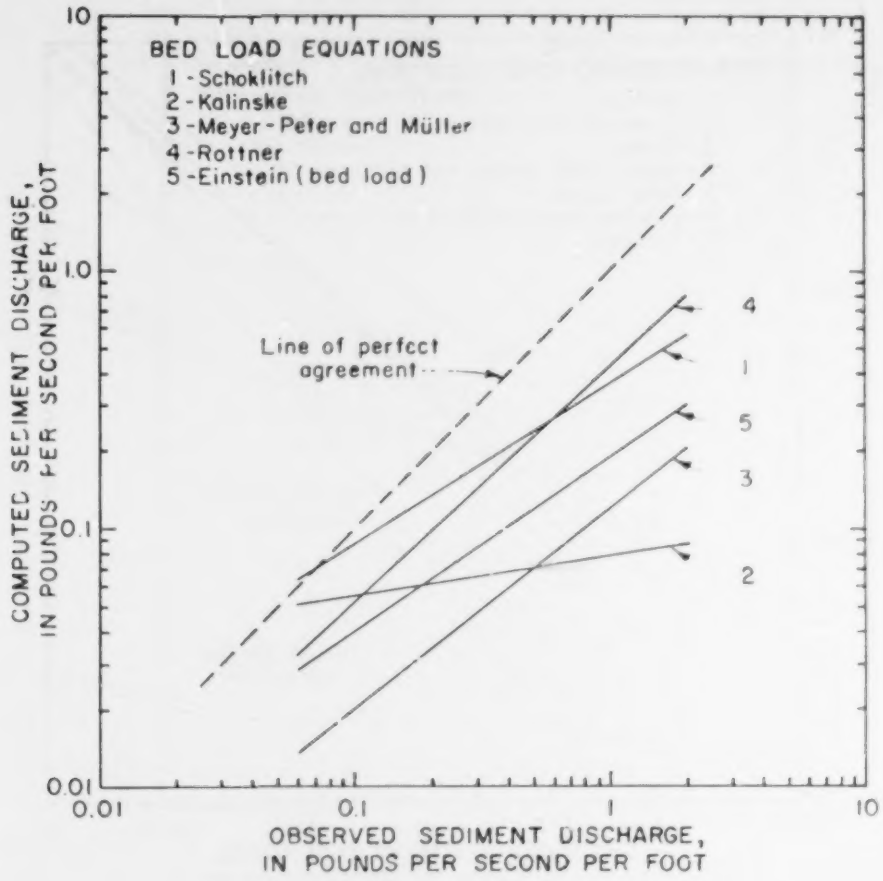

Figure 2.-- Comparison of bedload discharges computed by five formulas presented in this report to observed bed-material discharge, Niobrara River near Cody, Nebraska (Data from Colby and Hembree, 1955)

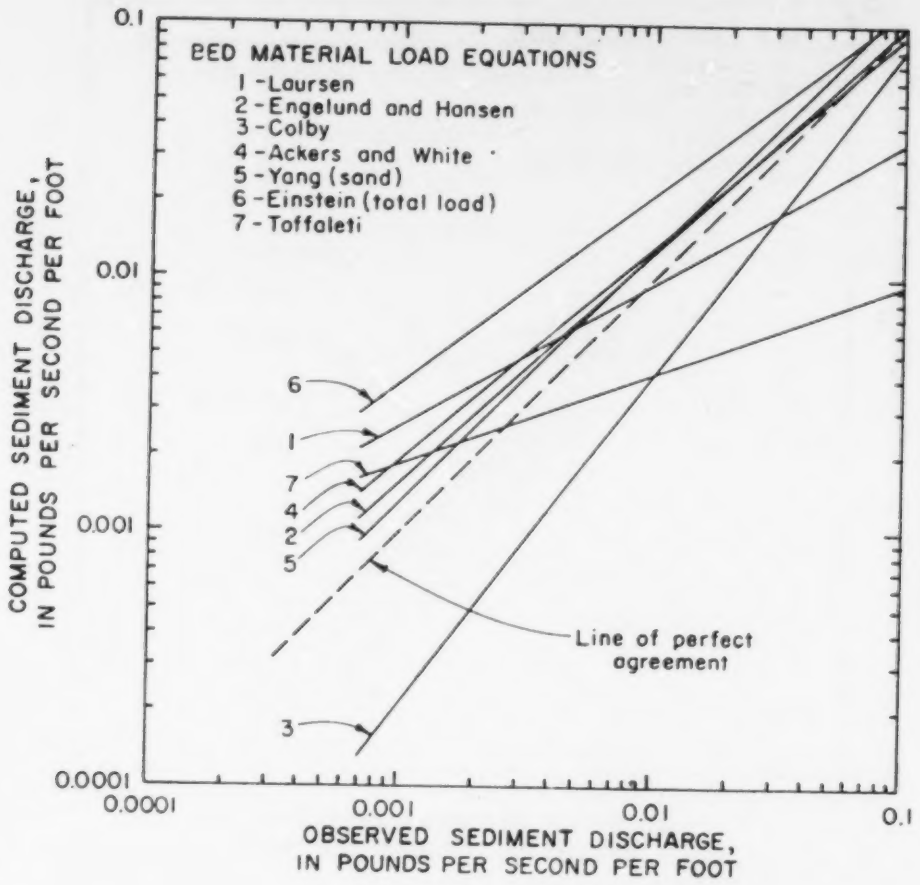

Figure 3.-- Comparison of bed-material discharges computed by seven formulas presented in this report to observed bed-material discharge, Mountain Creek (Data from Einstein, 1944)

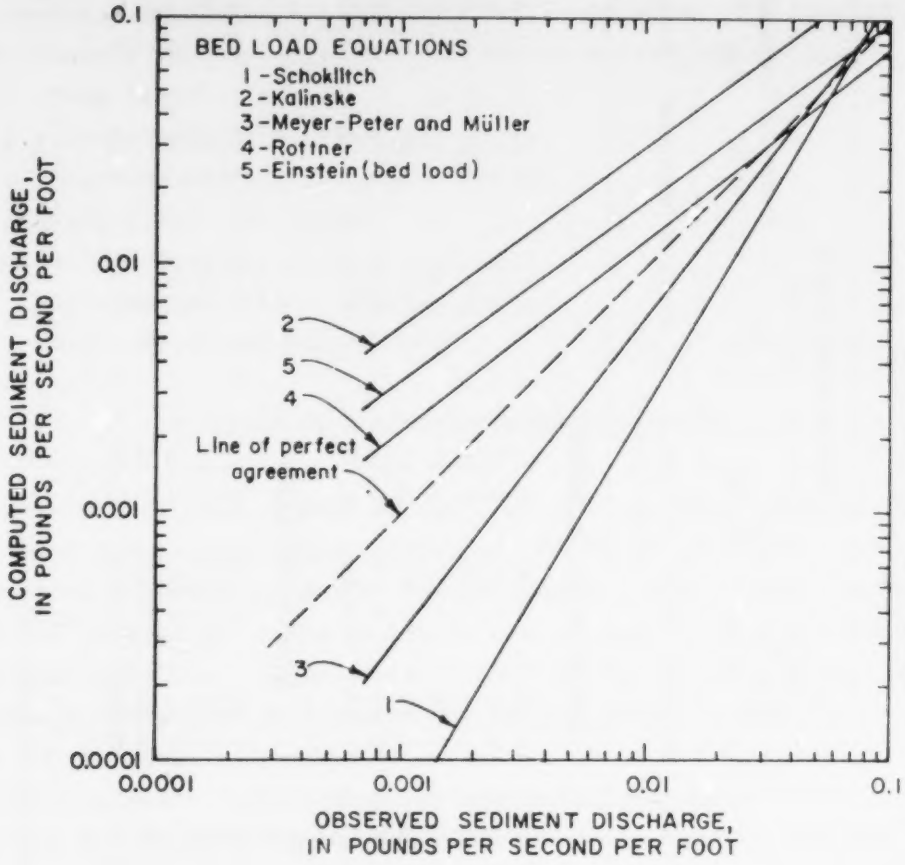

Figure 4.-- Comparison of bedload discharges computed by five formulas presented in this report to observed bed-material discharge, Mountain Creek (Data from Einstein, 1944)

Table 6.--Summary of comparisons of accuracies of seven bed-material formulas and five bedload formulas presented in this report

Author of formula	Discrepancy ratio[1]							
	Niobrara River data[2] 25 tests D_{50} 0.28 mm				Mountain Creek Data[3] 60 tests D_{50} 0.90 mm			
	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation
Bed-material formulas								
Laursen (1958)	0.27	1.39	0.70	0.35	3.27	4.25	1.25	0.62
Engelund & Hansen (1967)	0.97	2.68	1.51	0.37	0.72	3.12	1.36	0.38
Colby (1964)	0.35	1.25	0.78	0.24	0.00	0.69	0.40	0.17
Ackers and White (1973)	0.53	1.58	1.07	0.31	0.60	3.00	1.46	0.45
Yang (1973)	0.56	1.52	0.94	0.21	0.75	2.38	1.33	0.33
Einstein (1950)	0.30	0.98	0.57	0.16	0.96	6.38	2.51	0.85
Toffaleti (1968)	0.47	1.88	0.88	0.32	0.10	2.75	0.68	0.48
Bedload formulas								
Schoklitsch (1934)	0.38	1.20	0.59	0.22	0.00	1.20	0.28	0.29
Kalinske (1947)	0.08	0.74	0.25	0.18	1.41	9.00	3.63	1.22
Meyer-Peter & Müller (1948)	0.11	0.31	0.16	0.05	0.00	1.10	0.58	0.26
Rottner (1959)	0.28	0.80	0.47	0.11	0.57	3.25	1.44	0.46
Einstein (1950)	0.19	0.62	0.29	0.10	0.79	5.26	2.17	0.76

[1] Ratio between computed and measured sediment concentration.

[2] From Colby and Hembree (1955)

[3] From Einstein (1944)

The comparisons of accuracy of different formulas made by different investigators as given in tables 1-5 show more consistency when laboratory data with high degree of measurement accuracy are used. However, when field data are used, there seems to be a lack of consistency in the degree of accuracy rated by the investigators. This may be caused by the variance in the measurement accuracy of the selected field data. The comparison studies indicate that the most accurate bed-material formulas are:

Yang (1973) for sand,
Ackers and White (1973),
Engelund and Hansen (1967), and
Yang (1984) for gravel.

The best bedload formulas are:

Schoklitsch (1934), and
Meyer-Peter and Müller (1948)

SELECTION OF A SEDIMENT-DISCHARGE FORMULA

Sediment-discharge rates depend on such variables as flow velocity; energy slope; water temperature; size, gradation, and shape of the bed material and suspended-sediment particles; channel geometry and pattern; extent of bed surface covered by coarse material; rate of supply of fine material; and bed configuration. Large-scale variables such as hydrologic, geologic, and climatic conditions also affect the rate of sediment transport. Because of the range and number of variables, it is not possible to select a sediment transport formula that satisfactorily encompasses all the conditions that an investigator would encounter. A specific formula may be more accurate than others when applied to a particular river but it may not be accurate for other rivers. The following procedure, based on Yang (1988) with minor modifications, helps assist in the selection of a sediment transport formula.

1. Determine the type of field data available or measurable within the time, budget, and manpower limitations.
2. Examine all experimental and field data used to develop and verify each formula and select those formulas that are based on independent variables determined from step 1.
3. Compare the field situation and the limitations of formulas selected in step 2. If more than one formula can be used, calculate the rate of sediment discharge by each formula and

compare results.

4. Decide which formulas best agree with available measured sediment discharges and use these formulas to estimate the rate of sediment discharge during flow conditions when actual measurements are not available.
5. Consideration may be made of the following formulas in the absence of any measured sediment discharges for comparison:
   a. Meyer-Peter and Müller (1948) formula when the bed material is coarser than 5 mm.
   b. Einstein (1950) formula when bedload is a substantial part of the total-sediment discharge.
   c. Toffaleti (1968) formula for large sand-bed rivers.
   d. Colby (1964) formula for rivers with depths less than 10 feet and median bed-material values less than 0.8 mm.
   e. Yang (1973) sand formula for sand bed rivers.
   f. Yang (1984) formula for gravel transport when most of the bed material ranges from 2 to 10 mm.
   g. Acker and White (1973) or Engelund and Hansen (1967) formula for sand bed streams having subcritical flow.
   h. Laursen (1958) formula for shallow rivers with fine sand or coarse silt.
   i. Other formulas from the 13 presented in this report according to their degree of accuracy presented in the section "Evaluation of sediment discharge formulas".

To develop an empirical sediment discharge curve in the absence of a satisfactory sediment discharge formula, or to verify the sediment discharge trend from a selected formula use available data from the stream sediment discharge station and plot measured sediment discharge or concentration against water discharge, velocity, slope, depth, shear stress, stream power, or unit stream power. The curve with the least scatter and systematic deviation should to be selected as the sediment rating curve for the station.

COMPUTER PROGRAMS

Two versions of computer programs DISDATA and SEDDISCH are presented. The FORTRAN 77 language versions are for use on the Prime computer, and the BASIC language versions are for use on microcomputers.

Program DISDATA

The FORTRAN program for entering discharge data is organized in the form of a main program called DISDATA, six executable subroutines, and one BLOCK DATA subprogram (see Supplemental Data Section A). The counterpart BASIC program (see Supplemental Data Section C) contains minor variations of the FORTRAN program because of differences between the two computer languages. Both versions are interactive and the user is prompted for specific input. The main difference between the two versions is that the FORTRAN data file is random access; data sets are read and stored individually and the maximum number of data sets in the file is not fixed. The BASIC data file is sequential access; all data sets are read or stored in a single disk operation. To prevent loss of data, the BASIC program stores data on the disk whenever 10 data sets are entered into memory. The maximum number of data sets allowable in a single sequential file is 30.

When a listing of the data file is requested, the FORTRAN version of the program stores the listing on a file named DISDATA.LIST and later the listing is printed using a line printer. The BASIC version directs the output to be printed directly by an 80 column line printer without intermediate storage.

Data Input

Discharge data are entered by keyboard and are stored in a file called DISCH.DAT or a user-specified file. The following variables form a data set:

LOC - Location name, or other identifiers such as date and time;
W - Top width, in ft;
Y - Mean depth, in ft;

V - Mean velocity, in ft/s;

S - Water surface slope, in ft per ft;

TEMP - Water temperature, in °C;

D35 - Particle size, in mm, at which 35 percent of the bed material by weight is finer. Enter zero if not required.

D50 - Particle size, in mm, at which 50 percent of the bed material by weight is finer.

D65 - Particle size, in mm, at which 65 percent of the bed material by weight is finer. Enter zero if not required.

D90 - Particle size, in mm, at which 90 percent of the bed material by weight is finer. Enter zero if not required.

Stevens and Hubbell (1986) presented a computer program to compute D35, D50, D65 and D90 from particle size data.

Bed-material particle size data are entered depending on the value of the option code, NSZ, selected at the start of the run:

1. No size distribution data to be entered. Zero values are given to the percent-in-class variables (PCT) for the following 11 size fractions:
    1. 0.016 - 0.062 mm
    2. 0.062 - 0.125 mm
    3. 0.125 - 0.250 mm
    4. 0.250 - 0.500 mm
    5. 0.500 - 1.000 mm
    6. 1.000 - 2.000 mm
    7. 2.000 - 4.000 mm
    8. 4.000 - 8.000 mm
    9. 8.000 - 16.000 mm
    10. 16.000 - 32.000 mm
    11. 32.000 - 64.000 mm.
2. Percent-finer values (PF) are entered for 11 sizes from 0.062 to 64 mm. Zeroes are entered for the percent-finer value for all sizes for which no value was defined. Percent-in-class values are computed.
3. Percent-in-class values are entered for 11 sizes from 0.062 to 64 mm. Zeros are entered for the percent-in-class value for all sizes for which no value was defined. Two data files, each

containing one data set, are shown in Section E of the supplemental data at the back of this report. Size fraction data were not entered in file REPT2.DAT.

Program Description

The program is initiated by opening a data file called DISCH.DAT or a user-named file. A file-option code, NFL, is entered to do one of the following functions:

1. Is to start a new data file;
2. Is to add to an existing data file.

If NFL > 1, the number of data sets, NSET, is read from the data file; otherwise, NSET is set to 0.

A program option code, NC, is entered to do one of the following functions:

0. Is to end run;
1. Is to add data;
2. Is to correct one or more data sets;
3. Is to display data on screen; and
4. Is to list data on printer.

When NC = 0, the data file is closed and the run ends.

When NC = 1, data sets are added by the following procedure:

A. The value of NSZ, the size fraction input option is entered.
   1. Is for no size fraction data to be entered;
   2. Is to enter percent-finer values, PF, for the 11 size diameters; and
   3. Is to enter percent-in-class values, PCT, for the 11 size fractions.

B. The option to enter more data is selected (1 for yes or 2 for no). If the response is no, the program goes back for another entry of the program-option code, NC.

C. NSET is increased by one.

D. Subroutine DAIN is accessed to enter a set of data as follows:
   1. Values of LOC, width, depth, velocity, slope, temperature, D35, D50, D65, and D90 are entered;
   2. Percent finer, PF, and percent-in-class, PCT, values are set to zero;
   3. If NSZ = 1, the program goes to step E;

4. If NSZ = 2, percent finer values are entered and the program goes to step E; or
5. If NSZ = 3, percent-in-class values are entered and the program goes to step E.

E. After subroutine DALIST is accessed to list the data set on the screen, an option code is entered.
1. Is to accept the data as correct;
2. Is to reenter the entire data set; and
3. Is to correct part of the data set.

If the data set is correct, option 1, subroutine DAWRITE is accessed to write the data set on the data file, and the program goes back to step B for another data set. If the entire data set is to be reentered, option 2, the program goes back to step D. With option 3, subroutine DACORR is called. In subroutine DACORR, one of the following options is selected by entering the corresponding data-correction number:

0. Is to end corrections and go back to E;
1. Is to change LOC;
2. Is to change width;
3. Is to change depth;
4. Is to change velocity;
5. Is to change slope;
6. Is to change temperature;
7. Is to change D35;
8. Is to change D50;
9. Is to change D65;
10. Is to change D90; and
11-21. Are to change PCT values 1-11.

For numbers 1-21, after the current value is displayed, a new value is entered; then the above menu is redisplayed so a new data-correction number can be selected.

Data sets are corrected (NC = 2) by the following procedure:

A. The number of the data set to be corrected is entered; a value of 0 ends the corrections, and the program goes back for another entry of the program option code, NC. Otherwise in sequence, subroutine DAREAD is accessed called to input the data set from the data file, subroutine DALIST is accessed to list the data set

on the screen, and subroutine DACORR is accessed to permit values in the data set to be corrected. Correction procedures are identical to those previously described in step E.

B. Lastly, subroutine DALIST is accessed to list the corrected data set. If the data set still is not correct, the appropriate "change" option is selected. Otherwise, 0 is entered, and subroutine DAWRITE is accessed to write the data set on the data file. The program then goes back to step A.

Data sets are listed on the screen (NC = 3) in the following manner:

A. The starting and ending numbers of the data sets to be listed are entered. A starting value of 0 ends the listing, and the program goes back for another entry of the program option code, NC.

B. For each data set, subroutine DAREAD is accessed to input the data set from the data file, and subroutine DALIST is accessed to list the data set on the screen. The display is held on the screen until any number key is pressed. At the end of the last data set the program goes back to A.

Data sets are listed by the printer (NC = 4) by the following sequence:

A. The starting and ending numbers of the data sets to be printed are entered. A starting value of 0 ends the printing and the program goes back for another entry of the program-option code, NC.

B. For each data set, subroutine DAREAD is accessed to input the data set from the data file. The data set then is directed to an output file called DISDATA.LIST in the FORTRAN version of the program, or to a line printer in the BASIC version. At the end of the last data set the program goes back to A. The file DISDATA.LIST is printed using the line printer. Output from two data files that each contain one data set are shown in Supplemental Data Section E.

Program SEDDISCH

The FORTRAN program for computing sediment discharge is organized in the form of a main program called SEDDISCH and 20 subroutines (See Supplemental Data Section B). Program variables and counterpart text symbols used in the equations describing the sediment discharge formulas are defined in the section "Text symbols and program variables". The BASIC program (See Supplemental Data Section D) contains minor variations from the FORTRAN

program because of the differences between the two languages: however, the FORTRAN program description can be used in addition to the program variable definitions (See section "Text symbols and program variables") to understand the BASIC program.

Program output

Output from the FORTRAN version of program SEDDISCH is stored on a file named DISCH.OUT or a user-specified file, and later the output is printed using the line printer. The BASIC version directs the output to be printed directly by an 80-column line printer without intermediate storage.

FORTRAN-version outputs from three runs are shown in Supplemental Data Section F. The initial section of the output lists the input data and some of the computed variables. Run 1 (p. F1-F2) shows output from data file REPT1.DAT with size fraction listing. Run 2 (p. F3) also shows output from data file REPT1.DAT with only totals listed. Run 3 (p. F4), using data file REPT2.DAT, shows the results when size-fraction data are not entered.

Program description

Program SEDDISCH is begun by entering the value of NTYPE, the option number for the type(s) of sediment transport formulas to be used.

1. Is for bed-material discharge formulas.
2. Is for bedload discharge formulas.
3. Is for both types of discharge formulas.

LSF, the size fraction listing option is set equal to zero for no size fraction output listing. If NTYPE = 1 or NTYPE = 3 the numbers of the bed-material discharge formulas to be used are entered. The maximum number of formula numbers is 12. Formula numbers are:

1. Laursen formula (uses size fractions);
2. Engelund and Hansen formula (uses D50);
3. Colby formula (uses D50);
4. Ackers and White formula (using D50);
5. Ackers and White formula (using D35);
6. Yang sand formula (using D50);
7. Yang sand formula (using size fractions);
8. Yang gravel formula (using D50);

9. Yang gravel formula (using size fractions);
10. Combine 7 and 9 (uses size fractions);
11. Einstein formula (uses size fractions); and
12. Toffaleti formula (uses size fractions).

If NTYPE = 2 or NTYPE = 3, the numbers of the bedload discharge formulas to be used are entered. The maximum number of formula numbers is 8. Formula numbers are:

1. Schoklitsch formula (uses size fractions);
2. Kalinske formula (uses size fractions);
3. Meyer-Peter and Müller formula (uses size fractions)
   Use QS/Q = 1 and NS computed from equation;
4. Meyer-Peter and Müller formula (uses size fractions)
   For rectangular channel and enter roughness values;
5. Meyer-Peter and Müller formula (uses size fractions)
   For trapezoidal channel and enter roughness values;
6. Rottner formula (uses D50);
7. Einstein bedload formula (uses size fractions); and
8. Toffaleti formula - bedload part (uses size fractions).

For each formula selected that uses size fractions, the value of LSF is increased by 1. If LSF>0 at the end of the formula selection, an opportunity is given to change the value of LSF to 0 for no size-fraction output listing.

The program next accesses the data file created by program DISDATA -- either DISCH.DAT or the counterpart user specified file; opens an output file -- either DISCH.OUT or user-specified file; reads the number of data sets, NSAMP; and starts a computation loop (NS=1,NSAMP) for each data set.

The data set is read from the data file, and the following variables are computed:

1. XNU, Kinematic viscosity;
2. FV50, fall velocity of D50 computed by the Rubey (1933) equation;
3. U, Shear velocity; and
4. Q, water discharge.

Then the data set and computed variables are written on the output file.

If NTYPE = 1 or NTYPE = 3, the bed-material discharges are computed with the indicated formulas by accessing the appropriate subroutine(s). If NTYPE = 2 or NTYPE = 3, the bedload discharges are computed with the indicated formulas by accessing the appropriate subroutine(s). The computed sediment concentration, C, sediment discharge per unit width, UGS, and sediment discharge, GS, are written on the output file. If LSF>0 the data are written for each size fraction for formulas that compute values for each size fraction (See Supplemental Data Section F, p. F1-F2.).

The program then goes back to read another set of data from the data file. When all data sets have been computed, the program terminates.

SUMMARY

The assumptions used and theoretical basis of thirteen fluvial sediment-discharge formulas, five bedload discharge formulas and eight bed-material discharge formulas, are presented. Selection of the formulas was based on; 1) has some theoretical background, 2) has been tested by original author and independent investigator(s), and 3) has been commonly used by engineers and researchers. A review of comparisons made by different investigators of measured flume and field data with computed results from the formulas indicate that the bedload formulas of Schoklitch (1934) and Meyer-Peter and Müller (1948); and the bed-material formulas of Yang (1973), Ackers and White (1973), and Engelund and Hansen (1967) for sand, and Yang (1984) for gravel are the most reliable. A procedure, based on comparisons of data used to develop the formula with available data and a review of the formula background, is given to aid in the selection of an appropriate formula for given situations.

FORTRAN 77 language and BASIC language versions of computer programs are presented for inputing data (DISDATA) and for computing sediment discharge (SEDDISCH) by formulas selected by the user from the 13 described formulas.

REFERENCES CITED

Ackers, Peter, and White, W.R., 1973, Sediment transport--new approach and analysis: American Society Civil Engineers, Journal of the Hydraulics Division, v. 99, no. HY11, Proc Paper 10167, p. 2041-2060.

Alonso, C.V., 1980, Selecting a formula to estimate sediment transport capacity in nonvegetated channels in CREAMS (A field scale model for chemicals, runoff, and erosion from agricultural management system, Knisel, W. G., (ed.): U.S. Department of Agriculture, Conservation Research Report no. 26, ch. 5, p. 426-439.

American Society of Civil Engineers, 1975, Sedimentation engineering: Manuals and reports on engineering practice - no. 54, Vanoni, V.A., (ed.), American Society Civil Engineers, New York, p. 190-230.

-----, 1982, Relationships between morphology of small streams and sediment yield: Task Committee on Relations between morphology of small streams and sediment yield, American Society Civil Engineers, Journal of the Hydraulics Division, v. 108, no. HY 11, pp. 1328-1365.

Bagnold, R.A., 1966, An approach to the sediment transport problem from general physics: U.S. Geological Survey Professional Paper 422-I, 37 p.

Bathurst, J.C., 1985, Literature review of some aspects of gravel-bed rivers: Wallingford, Oxfordshire, UK, Institute of Hydrology, 190 p.

Brownlie, W.R., 1981, Prediction of flow depth and sediment discharge in open channels: Pasadena, Calif., W. M. Keck Lab. of Hydraulics and Water Resources, California Institute of Technology, 232 p.

Colby, B.R., 1964, Discharge of sands and mean-velocity relationships in sand-bed streams: U.S. Geological Survey Professional Paper 462-A, 47 p.

Colby, B.R., and Hembree, C.H., 1955, Computations of total sediment discharge Niobrara River near Cody, Nebraska: U.S. Geological Survey Water-Supply Paper 1357, 187 p.

Einstein, H.A., 1944, Bed load transportation in Mountain Creek: U.S. Soil Conservation Service, SCS-TP-55, 50 p.

----- 1950, The bed-load function for sediment transportation in open channel flows: U.S. Department Agriculture Technical Bulletin 1026, 70 p.

Einstein, H.A., and Barbarossa, N., 1952, River channel roughness: Transaction American Society Civil Engineers, v. 117, paper 2528, p. 1121-1146.

Engelund, Frank, and Hansen, Eggert, 1967, A monograph on sediment transport in alluvial streams: Danish Technical Press (Teknisk Forlag), 62 p.

Gilbert, G.K., 1914, The transportation of debris by running water: U.S. Geological Survey Professional Paper 86.

Johnson, J.W., 1943, Laboratory investigations on bed-load transportation and bed roughness: U.S. Department Agriculture Report SCS-TP-50, 16 p.

Kalinske, A.A., 1947, Movement of sediment as bed load in rivers: American Geophysical Union Transactions, v. 28, p. 615-620.

Keulegan, G.H., 1938, Laws of turbulent flow in open channels: U.S. National Bureau Standards, Journal Research, v. 21, no. 6, p. 707-741.

Laursen, E.L., 1958, The total sediment load of streams: American Society Civil Engineers, Journal of the Hydraulics Division, v. 84, no. HY1, Proc. Paper 1530, p. 1-36.

Li, R.M., 1974, Mathematical modeling of response from small watersheds: Fort Collins, Colo., Colorado State University, unpublished Ph.D. dissertation, appendix A, p. 156-169.

Meyer-Peter, E., and Müller, R., 1948, Formulas for bed-load transport: Stockholm, Sweden, International Association for Hydraulic Structures Research, 2d Meeting., p. 39-64.

Moore, I.D., and Burch, G.L., 1986, Sediment transport capacity of sheet and rill flow: Application of unit stream power theory: Water Resources Research, v 22, no. 8, p. 1350-1360.

Rottner, J., 1959, A formula for bed-load transportation: La Houille Blanche, v. 14, no. 3, pp. 285-307.

Rubey, W.W., 1933, Settling velocities of gravel, sand, and silt particles: American Journal Science, 5th series, v. 25, no. 148, p. 332.

Schoklitsch, A., 1934, Der Geschiebetrieb und die Geschiebefracht: Wasserkraft und Wasserwirtschaft, v. 29, no. 4, p. 37-43.

Schulits, Sam, 1935, The Schoklitsch bedload formula: Engineering, v. 139, p. 644-646, 987.

Schulits, Sam, and Hill, R.D., Jr., 1968, Bedload formulas--part A, a selection of bedload formulas, part B, Program listings for bedload formulas: University Park, Pa., The Pennsylvania State University, College of Engineering, 202 p.

Sheppard, J. R., 1960, Investigation of Meyer-Peter, Müller bedload formulas: Denver, Colo., U.S Department of Interior, Bureau of Reclamation, 22 p.

Stevens, Jr., H.H., and Hubbell, D.W., 1986, Computer programs for computing particle-size statistics: U.S. Geological Survey Water-Resources Investigations Report 86-4141, 70 p.

Strickler, K., 1923, Beiträge zur Frage der Geschwindigkeitsformel und der Rauhigkeitszahlen für Strom Kanäle und geschlossene Leitungen: Mitt. no. 16 des Eidgenössische Amtes für Wasser wirtschaft, Bern, Switzerland.

Toffaleti, F.B.,1968, A procedure for computation of the total river sand discharge and detailed distribution, bed to surface: Committee on Channel Stabilization, U.S. Army Corps of Engineers Waterways Experiment Station Technical Report. no. 5, 177 p.

U.S. Inter-Agency Committee on Water Resources, Subcommittee on Sedimentation, 1957, Some fundamentals of particle size analysis: Report 12 of A study of methods used in measurement and analysis of sediment loads in streams, 55 p.

White, W.R., Milli, H., and Crabbe, A.D., 1975, Sediment transport theories--a review: London, England, Proceedings of Institution of Civil Engineers, Part 2, no. 59, p. 265-292.

----- 1978, Sediment transport--an appraisal of available methods, v. 1 - summary of existing theories, v. 2 - performance of theoretical methods when applied to flume and field data: Wallingford, England, Report no. IT 119, Hydraulics Research Station, 130 p.

Yang, C.T., 1973, Incipient motion and sediment transport: American Society Civil Engineers, Journal of the Hydraulics Division, v. 99, no. HY10, Proc. Paper 10067, p. 1679-1704.

----- 1976, Discussion of sediment transport theories--a review: London, England, Proceedings of Institution Civil Engineers, Part 2, no. 61, p. 803-810.

----- 1984, Unit stream power equation for gravel: American Society Civil Engineers, Journal of Hydraulics Division, v. 110, no. HY12, p. 1783-1797.

----- 1988, Sediment transport and unit stream power in Civil Engineering Practice, Cheremisineff, P.E., Cheremisineff, N.P. and Cheng, S.L., (eds.): v. 5, ch. 8, Technomic Publishing Company Inc., Lancaster, PA, pp. 265-289.

Yang, C.T., and Molinas, A.M., 1982, Sediment transport and unit stream power function: American Society Civil Engineers, Journal of the Hydraulics Division, v. 108, no. HY6, p. 774-793.

Yang, C.T., and Stall, J.B., 1976, Applicability of unit stream power equation: American Society Civil Engineers, Journal of the Hydraulics Division, v. 102, no. HY5, p. 559-568.

TEXT SYMBOLS AND PROGRAM VARIABLES

TEXT SYMBOL	PROGRAM VARIABLE	
A	AA	Value of the Froude number at nominal initial motion (Ackers and White, 1973)
A	AVAL	Dimensionless distance of the lower limit of integration (Einstein, 1950)
A	A	A correction factor which replaces Einstein's (1950) ξ, Y, and θ (Toffaleti, 1968)
A	A	Coefficient (Colby, 1964)
AF	AF	Temperature adjustment coefficient (Colby, 1964)
AM	AM	U'_* times 10 (Toffaleti, 1968)
B	B	Bottom width of trapezoidal channel, in feet (Meyer-Peter and Müller, 1948)
B	B	Exponent (Colby, 1964)
$\overline{C}$	---	Mean concentration of bed-material discharge, in percent by weight (Laursen, 1958)
C	C	Concentration of bed-material discharge, in parts per million by weight
---	CI	Concentration of bed-material discharge for a size fraction, in parts per million by weight
CF	CF	Temperature adjustment coefficient (Colby, 1964)
C_A	CA	Coefficient in the general function (Ackers and White, 1973)
C_a	---	Suspended-sediment concentration at distance "a" above the bed (Einstein, 1950)
C_i	CI	Computed sediment concentration in the size fraction, i
C_v	CV	Velocity distribution parameter (Toffaleti, 1968)
C_y	---	Suspended-sediment concentration at distance "y" above the bed (Einstein, 1950)
C_z	CZ	A temperature related parameter used in evaluating ZOM (Toffaleti, 1968)

TEXT SYMBOL	PROGRAM VARIABLE	
D	---	Mean grain diameter, in in. (Schoklitsch, 1934)
DD	DD	Two times the bed sediment grain diameter (Toffaleti, 1968)
D_{si}	DFT	Mean grain diameter , in ft, of the sediment in size fraction, i, or meters in the original equation of Meyer-Peter and Müller (1948)
D_{35}	D35	Particle size, in mm, at which 35 percent of the bed material by weight is finer
D_{35}	DF35	Particle size, in ft, at which 35 percent of the bed material by weight is finer
D_{50}	D50	Median grain diameter or particle size, in mm, at which 50 percent of the bed material by weight is finer
D_{50}	DF50	Median grain diameter or particle size, in ft, at which 50 percent of the bed material by weight is finer
D_{65}	D65	Particle size, in mm, at which 65 percent of the bed material by weight is finer
D_{65}	DF65	Particle size, in ft, at which 65 percent of the bed material by weight is finer
D_{90}	D90	Particle size, in mm, at which 90 percent of the bed material by weight is finer, or meters in original equation of Meyer-Peter and Müller (1948)
D_m	DM	Effective diameter, in mm, of the bed-material mixture, or meters in original equation of Meyer-Peter and Müller (1948)
D_{gr}	DGR	Dimensionless grain diameter (Ackers and White, 1973)
d	Y	Mean depth, in ft, or meters in original equation of Meyer-Peter and Müller (1948)
f	---	Denotes function of
F1	F1	Exponent in the point-discharge equation in the lower zone (Toffaleti, 1968)
F2	F2	Exponent in the point-discharge equation in the middle zone (Toffaleti, 1968)
F3	F3	Exponent in the point-discharge equation in the upper zone (Toffaleti, 1968)

TEXT SYMBOL	PROGRAM VARIABLE	
F4	F4	Exponent of the integrated-discharge equation in the lower zone (Toffaleti, 1968)
F5	F5	Exponent of the integrated-discharge equation in the middle zone (Toffaleti, 1968)
F6	F6	Exponent of the integrated-discharge equation in the upper zone (Toffaleti, 1968)
F_{gr}	---	Dimensionless sediment mobility number (Ackers and White, 1973)
---	FV50	Fall velocity of D_{50}, in ft/s, computed by Rubey equation
f'	---	Friction factor (Engelund and Hansen, 1967)
G_s	---	Bedload discharge, in lb/s (Schoklitsch, 1934)
GA	GA	Integrated bed-material discharge, in t/d, for a size fraction in the lower zone; bed to YA (Toffaleti, 1968)
GB	GB	Integrated bed-material discharge, in t/d, for a size fraction in the middle zone; YA to YB (Toffaleti, 1968)
GBL	UGSI	Bedload discharge, in t/d (Toffaleti, 1968)
GC	GC	Integrated bed-material discharge, in t/d, for a size fraction in the upper zone; YB to surface (Toffaleti, 1968)
GF	GFB	Discharge, in t/d per ft of width, moving in the vertical section between levels from 2 times the grain diameter to YA, and with the assumption that the bed is composed entirely of one sand fraction (Toffaleeti, 1968)
G_{gr}	GGR	Dimensionless sediment transport rate (Ackers and White)
G_T	UGSI	Bed-material discharge, in t/d (Toffaleti, 1968)
g	G	Acceleration of gravity, in ft/s/s or m/s/s in original equation of Meyer-Peter and Müller (1948)
g_s	UGS	Sediment discharge, in lb/s per ft of width, or t/s per m of width in original equation of Meyer-Peter and Müller (1948)

TEXT SYMBOL	PROGRAM VARIABLE	
---	UGSI	Sediment discharge, in lb/s per ft of width, for a size fraction
---	GS	Sediment discharge, in t/d
H	H	Side slope of a trapezoidal channel, in ft per ft (Meyer-Peter and Müller, 1948)
i_b	PCT	Fraction, by weight, of bed material in a given size fraction
$i_B q_B$	UNITBD	Bedload discharge for a size fraction, in lb/s per ft of width (Einstein, 1950)
$i_T q_T$	UGSI	Bed-material discharge for a size fraction, in lb/s per ft of width (Einstein, 1950)
I_1	FI1	Integral value (Einstein, 1950)
I_2	FI2	Integral value (Einstein, 1950)
J_1	FJ1	Integral function (Einstein, 1950)
J_2	FJ2	Integral function (Einstein, 1950)
K_s	---	Coefficient of bed roughness (Meyer-Peter and Müller, 1948)
K_r	---	Coefficient of particle roughness (Meyer-Peter and Müller, 1948)
---	LOC	Location name or other identifiers such as date and time
m	S1	Summation of all size fractions of i_b/D_{si} for all size fractions in the bed-material mixture (Kalinske, 1947)
m	AM	Exponent in the sediment transport function (Ackers and and White, 1973)
n	---	Number of size fractions in the bed-material mixture
n	AN	Transition exponent depending on sediment size (Ackers and White, 1973)
---	NC	Program DISDATA option code
n_s	NS	Manning's roughness value for the bed
n_m	NM	Roughness value for the total channel for Meyer-Peter and Müller (1948) equation (Sheppard, 1960)
---	NSZ	Bed-material size data entry option code
---	NFL	Program file option code
---	NSET	Number of data sets in the data file

TEXT SYMBOL	PROGRAM VARIABLE	
n_w	MW	Roughness value for the channel sides for Meyer-Peter and Müller (1948) equation (Sheppard, 1960)
P	P	Parameter of total transport (Einstein, 1950)
P	---	Kinematic viscosity times 10 (Toffaleti, 1968)
P_i	---	The proportion of the total bed area occupied by the sediment particles in size fraction, i (Kalinske, 1947)
--	PF	Bed-material percent-finer values
PAM	PAM	Parameter used to evaluate A (Toffaleti, 1968)
Q	Q	Water discharge, in ft^3/s, or l/s in original equation of Meyer-Peter and Müller (1948)
Q_s	QS	That part of the water discharge apportioned to the bed, in ft^3/s, or l/s in original equation of Meyer-Peter and Müller (1948)
q	---	Water discharge, ft^3/s per ft of width
q_o	---	Critical water discharge, in ft^3/s per ft of width, for sediment diameter D_{si} (Schoklitsch, 1934)
R_b	RB	Hydraulic radius, in ft (Einstein, 1950)
R'_b	RBP	Hydraulic radius with respect to the grain, in ft (Einstein, 1950)
R''_b	RBPP	Hydraulic radius for channel irregularities, in ft (Einstein, 1950)
S	S	Energy gradient, in ft per ft
S_g	SG	Specific gravity of the bed sediment
SI	SI	Variable used in the evaluation of ZOM (Toffaleti, 1968)
---	TEMP	Water temperature, in °C
T	T	A parameter that includes the constants and those components of the shear force that are a function of water temperature (Toffaleti, 1968)
TDF	TDF	Water temperature, in °F (Toffaleti, 1968)
$\bar{U}_g$	---	Average velocity of particles, in ft/s, in a size fraction, i (Kalinske, 1947)
$\bar{U}$	---	Mean velocity of flow, in ft/s, at the grain level (Kalinske, 1947)

TEXT SYMBOL	PROGRAM VARIABLE	
U'_*	SVP	Shear velocity, in ft/s, with respect to the grain (Einstein, 1950, and Toffaleti, 1968)
UBL	UBL	Concentration of the bedload layer, in lb/ft^3, considering the bed composed entirely of the sand fraction under consideration (Toffaleti, 1968)
UD	UD	Point velocity at y=2D (Toffaleti, 1968)
U1	U1	Correlation of V and U'_* (Toffaleti, 1968)
U2	U2	Parameter for evaluating U'_* (Toffaleti, 1968)
U3	U3	Parameter for evaluating U'_* (Toffaleti, 1968)
V	V	Mean velocity, in ft/s
V_*	U	Shear velocity, in ft/s
V_c	VC	Critical velocity, in ft/s (Colby, 1964)
V_{cr}	---	Average flow velocity, in ft/s, at incipient motion (Yang, 1973, and Yang, 1984)
W	W	Top width of channel, in ft
x	XR	Dimensionless transition parameter (Einstein, 1950)
X	---	Sediment discharge concentration in mass flux per unit mass flow rate (Ackers and White, 1973)
X	CAPX	Characteristic grain size of the mixture (Einstein, 1950)
Y	CAPY	Pressure correction in transition from smooth to rough (Einstein, 1950)
YA	YA	Distance, in ft, from the bed to the upper limit of the lower zone (Toffaleti, 1968)
YB	YB	Distance, in ft, from the bed to the upper limit of the middle zone (Toffaleti, 1968)
Y_c	YC	Coefficient relating critical tractive force to sediment size (Laursen, 1958)
Z	ZC	Exponent of suspended distribution (Einstein, 1950)
Z_v	ZV	Exponent of velocity distribution (Toffaleti, 1968)
ZOM	ZOM	Exponent of sand concentration distribution in the middle zone (Toffaleti, 1968)
α	---	Coefficient in the rough turbulent equation with a value of 10 (Ackers and White, 1973)
β_x	BETAX	Logarithmic function (Einstein, 1950)

TEXT SYMBOL	PROGRAM VARIABLE	
γ	---	Specific weight of water, in lb/ft^3, or 1 t/m^3 in original equation of Meyer-Peter and Müller, 1948
γ_s	GMS	Specific weight of sediment, in lb/ft^3
γ'_s	---	Specific weight of sediment under water, and equals 1.65 t/m^3 in the original equation of Meyer-Peter and Müller (1948)
δ	DELTA	Thickness, in ft, of the laminar sublayer (Laursen, 1958)
δ'	DELTA	Laminar sublayer thickness, in ft, for U'_* (Einstein, 1950)
Δ	DELT	Apparant roughness parameter (Einstein, 1950)
θ	---	Dimensionless shear parameter (Engelund and Hansen, 1967)
ρ	---	Density of water, in slugs per ft^3
τ_o	TO	Total shear at the bed, in lb/ft^3
τ_{ci}	T1	Critical tractive force, in lb/ft^2, for sediment in a size fraction, i (Kalinske, 1947)
τ_c	---	Critical shear stress for particles of a size fraction Laursen, 1958)
τ'_o	---	Bed shear stress due to grain resistence (Laursen, 1958)
ν	XNU	Kinematic viscosity, in ft^2/s
ξ	XI	"Hiding factor" for grains in the bed mixture (Einstein, 1950)
ϕ	---	Dimensionless sediment discharge (Engelund and Hansen, 1967)
ϕ_*	PHI	Intensity of transport for individual grain size (Einstein, 1950)
ψ	---	Intensity of shear on the particles of a size fraction (Einstein, 1950)
ψ_*	PSIS	Adjusted intensity of shear on particles of a size fraction (Einstein, 1950)
ω	FV	Fall velocity, in ft/s, of sediment particles of diameter D_{50}
ω_i	FVI	Fall velocity, in ft/s, of sediment particles of diameter D_{si}

SUPPLEMENTAL DATA--SECTION A.

FORTRAN PROGRAM DISDATA LISTING

```
      PROGRAM DISDATA                                                    DSDA  10
C                                                                        DSDA  20
C     ENTER SEDIMENT DISCHARGE PROGRAM DATA TO INPUT FILE DISCH.DATA     DSDA  30
C              OR USER SPECIFIED FILE.                                   DSDA  40
C                                                                        DSDA  50
      COMMON /AA/ LOC,VAR(9),PCT(11),PF(11),SIZELO(11),SIZEHI(11),       DSDA  60
     1 LABEL(10),NREC                                                    DSDA  70
      CHARACTER*80 LOC                                                   DSDA  80
      CHARACTER*20 DFILE                                                 DSDA  90
      CHARACTER*5 LABEL                                                  DSDA 100
      CHARACTER*1 RSP                                                    DSDA 110
    1 FORMAT (1H0,'SET NUMBER',I4)                                       DSDA 120
    2 FORMAT (1H1,'DATA STORED ON FILE ',A20 / 1H )                      DSDA 130
    3 FORMAT (1H ,I2,2X,A5,1X,A80)                                       DSDA 140
    4 FORMAT (1H ,3(I2,2X,A5,F10.3,7X),I2,2X,A5,F13.7)                   DSDA 150
    5 FORMAT (1H ,4(I2,2X,A5,F10.3,7X),I2,2X,A5,F10.3)                   DSDA 160
    6 FORMAT (1H ,2(I2,2F9.3,F7.2,5X),I2,2F9.3,F7.2)                     DSDA 170
    7 FORMAT (A20)                                                       DSDA 180
    8 FORMAT ('DATA STORED ON FILE  ',A20,'   NUMBER DATA SETS = ',I4)   DSDA 190
    9 FORMAT ('ENTER SET NUMBER   MAX =',I4,'   0 TO END')               DSDA 200
   10 FORMAT ('NUMBER DATA SETS =',I4)                                   DSDA 210
   11 FORMAT ('ENTER START SET NUMBER   MAX =',I4,'   0 TO END')         DSDA 220
   12 FORMAT ('ENTER END SET NUMBER   MAX =',I4)                         DSDA 230
   13 FORMAT (1H ,5X,'0. END RUN USING ',A20 / 1H ,5X,'1. ADD DATA TO ',DSDA 240
     1 A20 / 1H ,5X,'2. CORRECT DATA IN ',A20 / 1H ,5X,'3. DISPLAY DATA DSDA 250
     2IN ',A20 / 1H ,5X,'4. PRINT DATA IN ',A20 )                        DSDA 260
   14 FORMAT (1H ,'   PERCENT IN INDICATED SIZE FRACTION, IN MM')        DSDA 270
   15 FORMAT (1H ,5X,'1. ',A20,' IS A NEW FILE' / 1H ,5X,'2. ',A20,      DSDA 280
     1 ' IS AN EXISTING FILE')                                           DSDA 290
      DFILE='DISCH.DAT'                                                  DSDA 300
      CALL CLSCR(25)                                                     DSDA 310
      WRITE (1,*) 'ESTABLISH FILE NAME:'                                 DSDA 320
      WRITE (1,*) '                   '                                  DSDA 330
      WRITE (1,*) '      1 TO USE DISCH.DAT'                             DSDA 340
      WRITE (1,*) '      2 TO ENTER FILE NAME'                           DSDA 350
      CALL CLSCR(3)                                                      DSDA 360
      WRITE (1,*) 'ENTER NUMBER OF SELECTION'                            DSDA 370
      READ (1,*) I                                                       DSDA 380
      IF (I.LT.2) GO TO 30                                               DSDA 390
      CALL CLSCR(10)                                                     DSDA 400
      WRITE (1,*) 'ENTER DESIRED FILE NAME'                              DSDA 410
      READ (1,7) DFILE                                                   DSDA 420
   30 CALL CLSCR(10)                                                     DSDA 430
      WRITE (1,15) DFILE,DFILE                                           DSDA 440
      CALL CLSCR(3)                                                      DSDA 450
      WRITE (1,*) 'ENTER NUMBER OF SELECTION'                            DSDA 460
      READ (1,*) NFL                                                     DSDA 470
      IF (NFL.GT.1) GO TO 40                                             DSDA 480
      NSET=0                                                             DSDA 490
      NREC=1                                                             DSDA 500
      OPEN (10,FILE=DFILE,STATUS='NEW',ACCESS='DIRECT',RECL=40)          DSDA 510
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      GO TO 100                                                          DSDA 520
   40 NSZ=1                                                              DSDA 530
      OPEN (10,FILE=DFILE,STATUS='OLD',ACCESS='DIRECT',RECL=40)          DSDA 540
      READ (10,REC=1) NSET                                               DSDA 550
   50 CALL CLSCR(25)                                                     DSDA 560
      WRITE (1,13) DFILE,DFILE,DFILE,DFILE,DFILE                         DSDA 570
      CALL CLSCR(3)                                                      DSDA 580
      WRITE (1,*) 'ENTER NUMBER OF SELECTION'                            DSDA 590
      CALL CLSCR(10)                                                     DSDA 600
      READ (1,*) NC                                                      DSDA 610
      IF (NC.GT.4) GO TO 50                                              DSDA 620
      IF (NC.GT.0) GO TO 80                                              DSDA 630
      CALL CLSCR(10)                                                     DSDA 640
      WRITE (1,8) DFILE,NSET                                             DSDA 650
      WRITE (10,REC=1) NSET                                              DSDA 660
      CLOSE (10)                                                         DSDA 670
      CALL CLSCR (5)                                                     DSDA 680
      WRITE (1,*) 'END OF RUN'                                           DSDA 690
      CALL EXIT                                                          DSDA 700
   80 GO TO (90,200,300,400),NC                                          DSDA 710
   90 NREC=NSET*3+1                                                      DSDA 720
C     ENTER DATA                                                         DSDA 730
  100 CALL CLSCR(25)                                                     DSDA 740
      WRITE (1,*) 'METHOD OF ENTERING SIZE FRACTION'                     DSDA 750
      WRITE (1,*) '                '                                     DSDA 760
      WRITE (1,*) '     1. NO SIZE FRACTION DATA TO BE ENTERED'          DSDA 770
      WRITE (1,*) '     2. DATA ENTERED BY PERCENT FINER VALUES'         DSDA 780
      WRITE (1,*) '     3. DATA ENTERED BY PERCENT IN SIZE FRACTION'     DSDA 790
      CALL CLSCR(5)                                                      DSDA 800
      WRITE (1,*) 'ENTER NUMBER OF SELECTION'                            DSDA 810
      READ (1,*) NSZ                                                     DSDA 820
      IF (NSZ.GT.3) GO TO 100                                            DSDA 830
      IF (NFL.EQ.1.OR.NC.EQ.1) GO TO 120                                 DSDA 840
  110 CALL CLSCR(25)                                                     DSDA 850
      WRITE (1,*) 'INPUT MORE DATA:  1 FOR YES  2 FOR NO'                DSDA 860
      READ (1,*) I                                                       DSDA 870
      IF (I.EQ.1) GO TO 120                                              DSDA 880
      IF (NFL.GT.1) GO TO 50                                             DSDA 890
      WRITE (10,REC=1) NSET                                              DSDA 900
      CLOSE (10)                                                         DSDA 910
      GO TO 40                                                           DSDA 920
  120 NSET=NSET+1                                                        DSDA 930
  130 CALL DAIN (NSZ,NPF)                                                DSDA 940
  140 CALL DALIST (NSET,NSZ)                                             DSDA 950
      WRITE (1,*) '                                                      DSDA 960
      WRITE (1,*) '    1 FOR DATA OK'                                    DSDA 970
      WRITE (1,*) '    2 TO RE-ENTER COMPLETE SET OF DATA'               DSDA 980
      WRITE (1,*) '    3 TO CORRECT PART OF DATA SET'                    DSDA 990
      WRITE (1,*) 'ENTER NUMBER'                                         DSDA1000
      READ (1,*) I                                                       DSDA1010
      GO TO (160,130,150),I                                              DSDA1020
  150 CALL DACORR (NSET,NSZ,NPF)                                         DSDA1030
      GO TO 140                                                          DSDA1040
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  160 IF (NSZ.NE.2) GO TO 180                                          DSDA1050
      PCT(1)=PF(1)                                                     DSDA1060
      DO 170 I=2,NPF                                                   DSDA1070
      PCT(I)=PF(I)-PF(I-1)                                             DSDA1080
  170 CONTINUE                                                         DSDA1090
  180 CALL DAWRITE                                                     DSDA1100
      GO TO 110                                                        DSDA1110
C     CORRECT DATA                                                     DSDA1120
  200 CALL CLSCR(25)                                                   DSDA1130
      WRITE (1,9) NSET                                                 DSDA1140
      READ (1,*) NS                                                    DSDA1150
      IF (NS.EQ.0) GO TO 50                                            DSDA1160
      IF (NS.GT.NSET) GO TO 200                                        DSDA1170
      NREC=(NS-1)*3+1                                                  DSDA1180
      CALL DAREAD                                                      DSDA1190
      CALL DACORR (NS,NSZ,NPF)                                         DSDA1200
      NREC=(NS-1)*3+1                                                  DSDA1210
      CALL DAWRITE                                                     DSDA1220
      GOTO 200                                                         DSDA1230
C     LIST DATA ON SCREEN                                              DSDA1240
  300 CALL CLSCR(25)                                                   DSDA1250
      WRITE (1,11) NSET                                                DSDA1260
      READ (1,*) NS1                                                   DSDA1270
      IF (NS1.EQ.0) GO TO 50                                           DSDA1280
      IF (NS1.GT.NSET) GO TO 300                                       DSDA1290
      NREC=(NS1-1)*3+1                                                 DSDA1300
  310 CALL CLSCR(3)                                                    DSDA1310
      WRITE (1,12) NSET                                                DSDA1320
      READ (1,*) NS2                                                   DSDA1330
      IF (NS2.GT.NSET) GO TO 310                                       DSDA1340
      DO 320 NS=NS1,NS2                                                DSDA1350
      CALL DAREAD                                                      DSDA1360
      CALL DALIST (NS,NSZ)                                             DSDA1370
      WRITE (1,*) '                                                    DSDA1380
      WRITE (1,*) 'PUSH CARRIAGE RETURN TO CONTINUE'                   DSDA1390
      READ (1,'(A)') RSP                                               DSDA1400
  320 CONTINUE                                                         DSDA1410
      GO TO 300                                                        DSDA1420
C     LIST DATA ON PRINTER                                             DSDA1430
C     OUTPUT IS ON FILE DISDATA.LIST                                   DSDA1440
  400 OPEN (11,FILE='DISDATA.LIST',STATUS='NEW')                       DSDA1450
      WRITE (11,2) DFILE                                               DSDA1460
  410 CALL CLSCR(25)                                                   DSDA1470
      WRITE (1,11) NSET                                                DSDA1480
      READ (1,*) NS1                                                   DSDA1490
      IF (NS1.EQ.0) GO TO 490                                          DSDA1500
      IF (NS1.GT.NSET) GO TO 410                                       DSDA1510
      NREC=(NS1-1)*3+1                                                 DSDA1520
  420 CALL CLSCR(3)                                                    DSDA1530
      WRITE (1,12) NSET                                                DSDA1540
      READ (1,*) NS2                                                   DSDA1550
      IF (NS2.GT.NSET) GO TO 420                                       DSDA1560
      DO 480 NS=NS1,NS2                                                DSDA1570
```

```
      CALL DAREAD                                                        DSDA1580
      WRITE (11,1) NS                                                    DSDA1590
      I=1                                                                DSDA1600
      WRITE (11,3) I,LABEL(I),LOC                                        DSDA1610
      WRITE (11,4) (I,LABEL(I),VAR(I-1),I=2,5)                           DSDA1620
      WRITE (11,5) (I,LABEL(I),VAR(I-1),I=6,10)                          DSDA1630
      WRITE (11,14)                                                      DSDA1640
      DO 430 I=11,20,3                                                   DSDA1650
      J1=I                                                               DSDA1660
      J2=I+2                                                             DSDA1670
      IF (I.EQ.20) J2=21                                                 DSDA1680
      WRITE (11,6) (J,SIZELO(J-10),SIZEHI(J-10),PCT(J-10),J=J1,J2)       DSDA1690
  430 CONTINUE                                                           DSDA1700
  480 CONTINUE                                                           DSDA1710
      GO TO 410                                                          DSDA1720
  490 CLOSE (11)                                                         DSDA1730
      GO TO 50                                                           DSDA1740
      END                                                                DSDA1750


      BLOCK DATA                                                         BKDA  10
      COMMON /AA/ LOC,VAR(9),PCT(11),PF(11),SIZELO(11),SIZEHI(11),       BKDA  20
     1 LABEL(10),NREC                                                    BKDA  30
      CHARACTER*80 LOC                                                   BKDA  40
      CHARACTER*5 LABEL                                                  BKDA  50
      DATA LABEL /'  LOC','WIDTH','DEPTH',' VEL.','SLOPE','TEMP.',      BKDA  60
     1'  D35','  D50','  D65','  D90'/                                   BKDA  70
      DATA SIZELO /0.016,0.062,0.125,0.25,0.5,1.,2.,4.,8.,16.,32./       BKDA  80
      DATA SIZEHI /0.062,0.125,0.25,0.5,1.,2.,4.,8.,16.,32.,64./         BKDA  90
      END                                                                BKDA 100


      SUBROUTINE DAIN (NSZ,NPF)                                          DAIN  10
C     INPUT ONE SET OF DATA                                              DAIN  20
      COMMON /AA/ LOC,VAR(9),PCT(11),PF(11),SIZELO(11),SIZEHI(11),       DAIN  30
     1 LABEL(10),NREC                                                    DAIN  40
      CHARACTER*80 LOC                                                   DAIN  50
      CHARACTER*5 LABEL                                                  DAIN  60
    1 FORMAT (A80)                                                       DAIN  70
    2 FORMAT (F10.0)                                                     DAIN  80
    3 FORMAT ('ENTER PCT FINER THAN ',F6.3,' MM')                        DAIN  90
    4 FORMAT ('ENTER PCT MATERIAL FOR ',F6.3,' TO ',F6.3,                DAIN 100
     1 ' MM   (0 FOR NONE)')                                             DAIN 110
      CALL CLSCR(25)                                                     DAIN 120
      WRITE (1,*) 'ENTER LOCATION NAME (MAX 80 CHARACTERS)'              DAIN 130
      READ (1,1,ERR=999) LOC                                             DAIN 140
      WRITE (1,*) 'ENTER TOP WIDTH  (FT)'                                DAIN 150
      READ (1,2,ERR=999) VAR(1)                                          DAIN 160
      WRITE (1,*) 'ENTER AVERAGE DEPTH  (FT)'                            DAIN 170
      READ (1,2,ERR=999) VAR(2)                                          DAIN 180
      WRITE (1,*) 'ENTER AVERAGE VELOCITY  (FT/SEC)'                     DAIN 190
```

```
      READ (1,2,ERR=999) VAR(3)                                          DAIN 200
      WRITE (1,*) 'ENTER WATER SURFACE SLOPE  (FT/FT)'                   DAIN 210
      READ (1,2,ERR=999) VAR(4)                                          DAIN 220
      WRITE (1,*) 'ENTER WATER TEMPERATURE  (DEG C)'                     DAIN 230
      READ (1,2,ERR=999) VAR(5)                                          DAIN 240
      WRITE (1,*) 'ENTER D35  (MM)  OR 0 FOR NONE'                       DAIN 250
      READ (1,2,ERR=999) VAR(6)                                          DAIN 260
      WRITE (1,*) 'ENTER D50  (MM)'                                      DAIN 270
      READ (1,2,ERR=999) VAR(7)                                          DAIN 280
      WRITE (1,*) 'ENTER D65  (MM)  OR 0 FOR NONE'                       DAIN 290
      READ (1,2,ERR=999) VAR(8)                                          DAIN 300
      WRITE (1,*) 'ENTER D90  (MM)  OR 0 FOR NONE'                       DAIN 310
      READ (1,2,ERR=999) VAR(9)                                          DAIN 320
      CALL CLSCR(5)                                                      DAIN 330
      DO 40 I=1,11                                                       DAIN 340
      PF(I)=0                                                            DAIN 350
      PCT(I)=0                                                           DAIN 360
   40 CONTINUE                                                           DAIN 370
      IF (NSZ-2) 90,50,70                                                DAIN 380
   50 NPF=0                                                              DAIN 390
   60 NPF=NPF+1                                                          DAIN 400
      WRITE (1,3) SIZEHI(NPF)                                            DAIN 410
      READ (1,2,ERR=999) PF(NPF)                                         DAIN 420
      IF (PF(NPF).GT.99.9) RETURN                                        DAIN 430
      IF (NPF.LT.11) GO TO 60                                            DAIN 440
      RETURN                                                             DAIN 450
   70 DO 80 I=1,11                                                       DAIN 460
      WRITE (1,4) SIZELO(I),SIZEHI(I)                                    DAIN 470
      READ (1,2,ERR=999) PCT(I)                                          DAIN 480
   80 CONTINUE                                                           DAIN 490
   90 RETURN                                                             DAIN 500
  999 WRITE (1,*) 'STOPPED ON INPUT ERROR'                               DAIN 510
      ENDFILE (10)                                                       DAIN 520
      CLOSE (10)                                                         DAIN 530
      CALL EXIT                                                          DAIN 540
      END                                                                DAIN 550


      SUBROUTINE DAWRITE                                                 WRIT  10
C     WRITE ONE SET OF DATA TO FILE                                      WRIT  20
      COMMON /AA/ LOC,VAR(9),PCT(11),PF(11),SIZELO(11),SIZEHI(11),       WRIT  30
     1 LABEL(10),NREC                                                    WRIT  40
      CHARACTER*80 LOC                                                   WRIT  50
      CHARACTER*5 LABEL                                                  WRIT  60
      NREC=NREC+1                                                        WRIT  70
      WRITE (10,REC=NREC) LOC                                            WRIT  80
      NREC=NREC+1                                                        WRIT  90
      WRITE (10,REC=NREC) (VAR(I),I=1,9)                                 WRIT 100
      NREC=NREC+1                                                        WRIT 110
      WRITE (10,REC=NREC) (PCT(I),I=1,11)                                WRIT 120
      RETURN                                                             WRIT 130
      END                                                                WRIT 140
```

```
      SUBROUTINE DAREAD                                                  READ  10
C     READ ONE SET OF DATA FROM FILE                                     READ  20
      COMMON /AA/ LOC,VAR(9),PCT(11),PF(11),SIZELO(11),SIZEHI(11),       READ  30
     1 LABEL(10),NREC                                                    READ  40
      CHARACTER*80 LOC                                                   READ  50
      CHARACTER*5 LABEL                                                  READ  60
      NREC=NREC+1                                                        READ  70
      READ (10,REC=NREC,ERR=100,END=200) LOC                             READ  80
      NREC=NREC+1                                                        READ  90
      READ (10,REC=NREC,ERR=100,END=200) (VAR(I),I=1,9)                  READ 100
      NREC=NREC+1                                                        READ 110
      READ (10,REC=NREC,ERR=100,END=200) (PCT(I),I=1,11)                 READ 120
      RETURN                                                             READ 130
  100 WRITE (1,*) 'ENDING WITH READ ERROR'                               READ 140
      CLOSE (10)                                                         READ 150
      CALL EXIT                                                          READ 160
  200 WRITE (1,*) 'STOPPED AT END-OF-FILE'                               READ 170
      CLOSE (10)                                                         READ 180
      CALL EXIT                                                          READ 190
      END                                                                READ 200
```

```
      SUBROUTINE DACORR (NSET,NSZ,NPF)                                   CORR  10
C     CORRECT ONE SET OF DATA                                            CORR  20
      COMMON /AA/ LOC,VAR(9),PCT(11),PF(11),SIZELO(11),SIZEHI(11),       CORR  30
     1 LABEL(10),NREC                                                    CORR  40
      CHARACTER*80 LOC                                                   CORR  50
      CHARACTER*5 LABEL                                                  CORR  60
    2 FORMAT (A80)                                                       CORR  70
    3 FORMAT ('OLD ',A5,' VALUE IS ',F10.7)                              CORR  80
    4 FORMAT ('OLD ',A5,' VALUE IS ',F10.3)                              CORR  90
    5 FORMAT ('OLD PERCENT VALUE IS ',F7.2)                              CORR 100
    6 FORMAT ('OLD PCT FINER VALUE IS ',F7.2)                            CORR 110
  100 CALL DALIST (NSET,NSZ)                                             CORR 120
      WRITE (1,*) '          '                                           CORR 130
      WRITE (1,*) 'ENTER VALUE NUMBER (1-21)  0 TO END'                  CORR 140
      READ (1,*) L                                                       CORR 150
      IF (L.EQ.0) RETURN                                                 CORR 160
      IF (L.GT.21) GO TO 100                                             CORR 170
      IF (L.GT.1) GO TO 110                                              CORR 180
      WRITE (1,*) 'OLD LOCATION NAME IS '                                CORR 190
      WRITE (1,2) LOC                                                    CORR 200
      WRITE (1,*) 'ENTER NEW LOCATION NAME'                              CORR 210
      READ (1,2) LOC                                                     CORR 220
      GOTO 100                                                           CORR 230
  110 IF (L.GT.10) GO TO 140                                             CORR 240
      IF (L.NE.5) GO TO 120                                              CORR 250
      WRITE (1,3) LABEL(L),VAR(L-1)                                      CORR 260
      GO TO 130                                                          CORR 270
  120 WRITE (1,4) LABEL(L),VAR(L-1)                                      CORR 280
  130 WRITE (1,*) 'ENTER NEW VALUE'                                      CORR 290
      READ (1,*) VAR(L-1)                                                CORR 300
```

```
      GO TO 100                                                          CORR 310
  140 I=L-10                                                             CORR 320
      IF (NSZ.EQ.2) GO TO 150                                            CORR 330
      WRITE (1,5) PCT(I)                                                 CORR 340
      WRITE (1,*) 'ENTER NEW VALUE'                                      CORR 350
      READ (1,*) PCT(I)                                                  CORR 360
      GO TO 100                                                          CORR 370
  150 WRITE (1,6) PF(I)                                                  CORR 380
      WRITE (1,*) 'ENTER NEW VALUE'                                      CORR 390
      READ (1,*) PF(I)                                                   CORR 400
      IF (PF(I).GT.99.9.OR.I.GT.NPF) NPF=I                               CORR 410
      GO TO 100                                                          CORR 420
      END                                                                CORR 430



      SUBROUTINE DALIST (NSET,NSZ)                                       LIST  10
C     LIST ONE SET OF DATA ON SCREEN                                     LIST  20
      COMMON /AA/ LOC,VAR(9),PCT(11),PF(11),SIZELO(11),SIZEHI(11),       LIST  30
     1 LABEL(10),NREC                                                    LIST  40
      CHARACTER*80 LOC                                                   LIST  50
      CHARACTER*5 LABEL                                                  LIST  60
    1 FORMAT ('SET NUMBER',I4)                                           LIST  70
    2 FORMAT (I2,2X,A5,1X,A80)                                           LIST  80
    3 FORMAT (I2,2X,A5,F10.3,10X,I2,2X,A5,F12.7)                         LIST  90
    4 FORMAT (I2,2X,A5,F10.3,10X,I2,2X,A5,F10.3)                         LIST 100
    5 FORMAT (I2,2F9.3,F7.2,6X,I2,2F9.3,F7.2)                            LIST 110
    6 FORMAT (I2,F9.3,F7.2,6X,I2,F9.3,F7.2)                              LIST 120
      CALL CLSCR(25)                                                     LIST 130
      WRITE (1,1) NSET                                                   LIST 140
      I=1                                                                LIST 150
      WRITE (1,2) I,LABEL(I),LOC                                         LIST 160
      WRITE (1,4) (I,LABEL(I),VAR(I-1),I=2,3)                            LIST 170
      WRITE (1,3) (I,LABEL(I),VAR(I-1),I=4,5)                            LIST 180
      WRITE (1,4) (I,LABEL(I),VAR(I-1),I=6,10)                           LIST 190
      IF (NSZ.EQ.2) GO TO 60                                             LIST 200
      WRITE (1,*) '   PERCENT IN INDICATED SIZE FRACTION IN MM'          LIST 210
      WRITE (1,5) (I,SIZELO(I-10),SIZEHI(I-10),PCT(I-10),I=11,21)        LIST 220
      RETURN                                                             LIST 230
   60 WRITE (1,*) '   PERCENT FINER FOR INDICATED SIZE IN MM'            LIST 240
      WRITE (1,6) (I,SIZEHI(I-10),PF(I-10),I=11,21)                      LIST 250
      RETURN                                                             LIST 260
      END                                                                LIST 270



      SUBROUTINE CLSCR(N)                                                CLSC  10
C                                                                        CLSC  20
C     MOVE CURSER DOWN N LINES                                           CLSC  30
C                                                                        CLSC  40
      DO 10 I=1,N                                                        CLSC  50
      WRITE (1,*)                                                        CLSC  60
   10 CONTINUE                                                           CLSC  70
```

```
      RETURN                                                        CLSC  80
      END                                                           CLSC  90
```

SUPPLEMENTAL DATA--SECTION B.

FORTRAN PROGRAM SEDDISCH LISTING

```
      PROGRAM SEDDISCH                                                  SEDD  10
C                                                                       SEDD  20
C     COMPUTE BED MATERIAL & BED LOAD DISCHARGE BY SELECTED FORMULAS    SEDD  30
C                                                                       SEDD  40
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,  SEDD  50
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U, SEDD  60
     2 UGSI,V,W,XNU,Y                                                   SEDD  70
      CHARACTER*80 LOC                                                  SEDD  80
      CHARACTER*20 DFILE,OFILE                                          SEDD  90
      DIMENSION NOSEL(2,12),NOS(2)                                      SEDD 100
    1 FORMAT (1H ,5X,'1.  BED-MATERIAL DISCHARGE FORMULAS' / 1H ,5X,'2. SEDD 110
     1 BEDLOAD DISCHARGE FORMULAS' / 1H ,5X,'3.  BOTH TYPES OF FORMULAS SEDD 120
     2 ')                                                               SEDD 130
    2 FORMAT (1H ,10X,'BED-MATERIAL DISCHARGE FORMULA OPTIONS:' / 1H  / SEDD 140
     1 1H ,' 1.  LAURSEN FORMULA   (USES SIZE FRACTIONS)' / 1H ,' 2.  ENSEDD 150
     2GELUND AND HANSEN FORMULA  (USES D50)' / 1H ,' 3.  COLBY FORMULA  SEDD 160
     3 (USES D50)' / 1H ,' 4.  ACKERS AND WHITE FORMULA   (USING D50)' /SEDD 170
     4 1H ,' 5.  ACKERS AND WHITE  FORMULA   (USING D35)' / 1H ,' 6.  YASEDD 180
     5NG SAND FORMULA   (USING D50)' / 1H ,' 7.  YANG SAND FORMULA   (USSEDD 190
     6ING SIZE FRACTIONS)' / 1H ,' 8.  YANG GRAVEL FORMULA   (USING D50)SEDD 200
     7' / 1H ,' 9.  YANG GRAVEL FORMULA   (USING SIZE FRACTIONS)' /     SEDD 210
     8 1H ,'10.  COMBINE 7 AND 9   (USES SIZE FRACTIONS)'/ 1H ,'11.  EINSEDD 220
     9STEIN FORMULA   (USES SIZE FRACTIONS)' / 1H ,'12.  TOFFALETI FORMUSEDD 230
     1LA   (USES SIZE FRACTIONS)' )                                     SEDD 240
    3 FORMAT (1H ,'ENTER FORMULA NUMBER FOR COMPUTATION NUMBER',I4,      SEDD 250
     1 '   (0 TO END)' )                                               SEDD 260
    4 FORMAT (1H ,10X,'BEDLOAD DISCHARGE FORMULA OPTIONS:' / 1H  / 1H , SEDD 270
     1 '1.  SCHOKLITSCH FORMULA   (USES SIZE FRACTIONS)' / 1H ,'2.  KALISEDD 280
     2NSKE FORMULA   (USES SIZE FRACTIONS)' / 1H ,'3.  MEYER-PETER AND MSEDD 290
     3ULLER FORMULA   (USES SIZE FRACTIONS)' / 1H ,'    USE QS/Q=1 AND NSEDD 300
     4S COMPUTED FROM EQUATION' / 1H ,'4.  MEYER-PETER AND MULLER FORMULSEDD 310
     5A   (USES SIZE FRACTIONS)' / 1H ,'    FOR RECTANGULAR CHANNEL AND SEDD 320
     6ENTER ROUGHNESS VALUES' / 1H ,'5.  MEYER-PETER AND MULLER FORMULA SEDD 330
     7  (USES SIZE FRACTIONS)' / 1H ,'    FOR TRAPEZOIDAL CHANNEL AND ENSEDD 340
     8TER ROUGHNESS VALUES' / 1H ,'6.  ROTTNER FORMULA   (USES D50)' / 1SEDD 350
     9H ,'7.  EINSTEIN BEDLOAD FORMULA   (USES SIZE FRACTIONS)' / 1H ,'8SEDD 360
     1.  TOFFALETTI FORMULA - BEDLOAD PART   (USES SIZE FRACTIONS)')    SEDD 370
    5 FORMAT (1H ,'LIST RESULTS BY:' / 1H  / 1H ,'     1.  FOR EACH FRACSEDD 380
     1TION AND TOTAL' / 1H ,'     2.  TOTAL ONLY' )                     SEDD 390
    6 FORMAT (1H ,'ESTABLISH DATA FILE NAME:' / 1H  / 1H ,'     1.  USE SEDD 400
     1PROGRAMMED FILE NAME (DISCH.DAT)' / 1H ,'     2.  PROVIDE FILE NAMSEDD 410
     2E' )                                                              SEDD 420
    7 FORMAT (A20)                                                      SEDD 430
    8 FORMAT (1H ,'ESTABLISH OUTPUT FILE NAME:' / 1H  / 1H ,'     1.  USSEDD 440
     1E PROGRAMMED FILE NAME (DISCH.OUT)' / 1H ,'     2.  PROVIDE FILE NSEDD 450
     2AME' )                                                            SEDD 460
    9 FORMAT (1H1)                                                      SEDD 470
   10 FORMAT (1H ,A80 / 1H  / 1H ,'TOP WIDTH',12X,F8.2,' FEET      WATERSEDD 480
     1 SURF. SLOPE',6X,F10.7,' FT/FT' / 1H ,'MEAN DEPTH',13X,F6.2,' FEETSEDD 490
     2',6X,'D50',18X,F6.3,' MILLIMETERS' / 1H ,'MEAN VELOCITY',9X,F5.2,'SEDD 500
     3 FT/SEC',6X,'KINEMATIC VISCOCITY',9X,F11.8 / 1H ,'WATER DISCHARGE'SEDD 510
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     4,5X,F10.2,' CFS',6X,'SED. FALL VELOCITY',7X,F7.4,' FT/SEC' / 1H , SEDD 520
     5 'WATER TEMPERATURE',7X,F4.1,' DEG C' )                          SEDD 530
  11 FORMAT (1H0,10X,'COMPUTED BED-MATERIAL CONCENTRATION AND DISCHARGESEDD 540
     1 ' / 1H0,'FORMULA',42X,'CONC.   UNIT DISCH   DISCHARGE' / 1H ,50X,SEDD 550
     2 'PPM    LBS/SEC/FT   TONS/DAY' / 1H  )                          SEDD 560
  12 FORMAT (1H0,10X,'COMPUTED BEDLOAD CONCENTRATION AND DISCHARGE' /  SEDD 570
     1 1H0,'FORMULA',42X,'CONC.   UNIT DISCH   DISCHARGE' / 1H ,50X,'PPMSEDD 580
     2    LBS/SEC/FT   TONS/DAY' / 1H  )                              SEDD 590
  13 FORMAT (1H0 / 1H0,'* * * * * * * * * * * * * * * * * * * * * * *SEDD 600
     1 * * * * * * * * * * * * * * * *' / 1H0)                        SEDD 610
  14 FORMAT (1H0,'*** READ ERROR ON FILE ',A20,' ***' )               SEDD 620
  15 FORMAT (1H0,'*** END-OF-FILE ON FILE ',A20,' ***' )              SEDD 630
  16 FORMAT (1H ,'OUTPUT ON FILE ',A20 / 1H ,'END OF RUN' )           SEDD 640
C                                                                     SEDD 650
     DATA SIZELO/0.016,.062,.125,.25,.5,1,2,4,8,16,32/                SEDD 660
     DATA SIZEHI/0.062,0.125,0.25,0.5,1,2,4,8,16,32,64/               SEDD 670
     DO 20 I=1,11                                                     SEDD 680
     DIA(I)=(SIZELO(I)*SIZEHI(I))**.5                                 SEDD 690
     DFT(I)=DIA(I)/304.8                                              SEDD 700
  20 CONTINUE                                                         SEDD 710
     SG=2.65                                                          SEDD 720
     G=32.1725                                                        SEDD 730
     GMS=165.76                                                       SEDD 740
C                                                                     SEDD 750
C    ENTER FORMULA NUMBERS TO BE COMPUTED                             SEDD 760
C                                                                     SEDD 770
     NOS(1)=0                                                         SEDD 780
     NOS(2)=0                                                         SEDD 790
     LSF=0                                                            SEDD 800
  30 CALL CLSCR(25)                                                   SEDD 810
     WRITE (1,1)                                                      SEDD 820
     CALL CLSCR(3)                                                    SEDD 830
     WRITE (1,*) 'ENTER NUMBER FOR TYPE(S) OF FORMULAS TO BE USED'    SEDD 840
     READ (1,*) NTYPE                                                 SEDD 850
     IF (NTYPE.GT.3) GO TO 30                                         SEDD 860
     IF (NTYPE.EQ.2) GO TO 60                                         SEDD 870
     K=0                                                              SEDD 880
     N=1                                                              SEDD 890
  40 CALL CLSCR(25)                                                   SEDD 900
     WRITE (1,2)                                                      SEDD 910
     CALL CLSCR(3)                                                    SEDD 920
     WRITE (1,3) N                                                    SEDD 930
     READ (1,*) I                                                     SEDD 940
     IF (I.GT.12) GO TO 40                                            SEDD 950
     IF (I.EQ.0) GO TO 50                                             SEDD 960
     IF (I.EQ.1.OR.I.EQ.7.OR.I.GT.8) LSF=LSF+1                        SEDD 970
     K=K+1                                                            SEDD 980
     N=N+1                                                            SEDD 990
     NOSEL(1,K)=I                                                     SEDD1000
     IF (N.LE.12) GO TO 40                                            SEDD1010
  50 NOS(1)=K                                                         SEDD1020
  60 IF (NTYPE.EQ.1) GO TO 90                                         SEDD1030
     K=0                                                              SEDD1040
```

```
      N=1                                                                SEDD1050
   70 CALL CLSCR(25)                                                     SEDD1060
      WRITE (1,4)                                                        SEDD1070
      CALL CLSCR(3)                                                      SEDD1080
      WRITE (1,3) N                                                      SEDD1090
      READ (1,*) I                                                       SEDD1100
      IF (I.GT.8) GO TO 70                                               SEDD1110
      IF (I.EQ.0) GO TO 80                                               SEDD1120
      IF (I.LE.3.OR.I.GT.6) LSF=LSF+1                                    SEDD1130
      K=K+1                                                              SEDD1140
      N=N+1                                                              SEDD1150
      NOSEL(2,K)=I                                                       SEDD1160
      IF (N.LE.8) GO TO 70                                               SEDD1170
   80 NOS(2)=K                                                           SEDD1180
   90 IF (LSF.EQ.0) GO TO 110                                            SEDD1190
  100 CALL CLSCR(25)                                                     SEDD1200
      WRITE (1,5)                                                        SEDD1210
      CALL CLSCR(3)                                                      SEDD1220
      WRITE (1,*) 'ENTER LISTING SELECTION NUMBER'                       SEDD1230
      READ (1,*) I                                                       SEDD1240
      IF (I.GT.2) GO TO 100                                              SEDD1250
      IF (I.GT.1) LSF=0                                                  SEDD1260
C                                                                        SEDD1270
C     ESTABLISH DATA & OUTPUT FILES                                      SEDD1280
C                                                                        SEDD1290
  110 DFILE='DISCH.DAT'                                                  SEDD1300
      CALL CLSCR(25)                                                     SEDD1310
      WRITE (1,6)                                                        SEDD1320
      CALL CLSCR(3)                                                      SEDD1330
      WRITE (1,*) 'ENTER NUMBER OF SELECTION'                            SEDD1340
      READ (1,*) I                                                       SEDD1350
      IF (I.EQ.1) GO TO 120                                              SEDD1360
      CALL CLSCR(10)                                                     SEDD1370
      WRITE (1,*) 'ENTER DESIRED FILE NAME '                             SEDD1380
      READ (1,7) DFILE                                                   SEDD1390
  120 OPEN (5,FILE=DFILE,STATUS='OLD',FORM='UNFORMATTED')                SEDD1400
      OFILE='DISCH.OUT'                                                  SEDD1410
      CALL CLSCR(25)                                                     SEDD1420
      WRITE (1,8)                                                        SEDD1430
      CALL CLSCR(3)                                                      SEDD1440
      WRITE (1,*) 'ENTER NUMBER OF SELECTION'                            SEDD1450
      READ (1,*) I                                                       SEDD1460
      IF (I.EQ.1) GO TO 130                                              SEDD1470
      CALL CLSCR(10)                                                     SEDD1480
      WRITE (1,*) 'ENTER DESIRED FILE NAME '                             SEDD1490
      READ (1,7) OFILE                                                   SEDD1500
  130 OPEN (6,FILE=OFILE,STATUS='NEW')                                   SEDD1510
      WRITE (6,9)                                                        SEDD1520
C                                                                        SEDD1530
C     READ DATA AND COMPUTE DESIRED DISCHARGES                           SEDD1540
C                                                                        SEDD1550
      READ (5) NSAMP                                                     SEDD1560
      DO 700 NS=1,NSAMP                                                  SEDD1570
```

```
      SUMP=0                                                                SEDD1580
      READ (5,ERR=1000,END=1010) LOC                                        SEDD1590
      READ (5,ERR=1000,END=1010) W,Y,V,S,TEMP,D35,D50,D65,D90               SEDD1600
      READ (5,ERR=1000,END=1010) (PCT(I),I=1,11)                            SEDD1610
      DO 140 I=1,11                                                         SEDD1620
      SUMP=SUMP+PCT(I)                                                      SEDD1630
      PCT(I)=PCT(I)/100.                                                    SEDD1640
  140 CONTINUE                                                              SEDD1650
      COMP1=1.0334+.03672*TEMP+.0002058*TEMP*TEMP                           SEDD1660
      XNU=.00002/COMP1                                                      SEDD1670
      DF35=D35/304.8                                                        SEDD1680
      DF50=D50/304.8                                                        SEDD1690
      DF65=D65/304.8                                                        SEDD1700
      DF90=D90/304.8                                                        SEDD1710
      COMP2=6.*XNU                                                          SEDD1720
      FV50=((36.064*DF50**3+COMP2**2)**.5-COMP2)/DF50                       SEDD1730
      U=(G*Y*S)**(.5)                                                       SEDD1740
      Q=W*Y*V                                                               SEDD1750
      CALL CLSCR(25)                                                        SEDD1760
      WRITE (1,10) LOC,W,S,Y,D50,V,XNU,Q,FV50,TEMP                          SEDD1770
      CALL CLSCR(4)                                                         SEDD1780
      WRITE (6,10)LOC,W,S,Y,D50,V,XNU,Q,FV50,TEMP                           SEDD1790
      IF (NTYPE.EQ.2) GO TO 400                                             SEDD1800
      WRITE (6,11)                                                          SEDD1810
      DO 300 NO=1,NOS(1)                                                    SEDD1820
      IOS=NOSEL(1,NO)                                                       SEDD1830
      GO TO (150,160,170,180,180,190,200,190,200,200,210,220),IOS           SEDD1840
C                                                                           SEDD1850
C     LAURSEN FORMULA   (USES SIZE FRACTIONS)                               SEDD1860
C                                                                           SEDD1870
  150 CALL LASN                                                             SEDD1880
      GO TO 300                                                             SEDD1890
C                                                                           SEDD1900
C     ENGELUND AND HANSEN FORMULA                                           SEDD1910
C                                                                           SEDD1920
  160 CALL ENG                                                              SEDD1930
      GO TO 300                                                             SEDD1940
C                                                                           SEDD1950
C     COLBY FORMULA                                                         SEDD1960
C                                                                           SEDD1970
  170 CALL COLBY                                                            SEDD1980
      GO TO 300                                                             SEDD1990
C                                                                           SEDD2000
C     ACKERS AND WHITE FORMULA                                              SEDD2010
C                                                                           SEDD2020
  180 CALL ACK                                                              SEDD2030
      GO TO 300                                                             SEDD2040
C                                                                           SEDD2050
C     YANG SAND & GRAVEL FORMULAS USING D50                                 SEDD2060
C                                                                           SEDD2070
  190 CALL YAG50                                                            SEDD2080
      GO TO 300                                                             SEDD2090
C                                                                           SEDD2100
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C     YANG SAND & GRAVEL FORMULAS USING SIZE FRACTIONS                  SEDD2110
C                                                                       SEDD2120
  200 CALL YAGFR                                                        SEDD2130
      GO TO 300                                                         SEDD2140
C                                                                       SEDD2150
C     EINSTEIN FORMULA   (USES SIZE FRACTIONS)                          SEDD2160
C                                                                       SEDD2170
  210 CALL EINS (1)                                                     SEDD2180
      GO TO 300                                                         SEDD2190
C                                                                       SEDD2200
C     TOFFALETI FORMULA   (USES SIZE FRACTIONS)                         SEDD2210
C                                                                       SEDD2220
  220 CALL TOFF (1)                                                     SEDD2230
  300 CONTINUE                                                          SEDD2240
      WRITE (6,*) '           '                                         SEDD2250
  400 IF (NTYPE.EQ.1) GO TO 610                                         SEDD2260
      WRITE (6,12)                                                      SEDD2270
      DO 600 NO=1,NOS(2)                                                SEDD2280
      IOS=NOSEL(2,NO)                                                   SEDD2290
      GO TO (410,420,430,430,430,440,450,460),IOS                       SEDD2300
C                                                                       SEDD2310
C     SCHOKLITSCH FORMULA   (USES SIZE FRACTIONS)                       SEDD2320
C                                                                       SEDD2330
  410 CALL SCHOK                                                        SEDD2340
      GO TO 600                                                         SEDD2350
C                                                                       SEDD2360
C     KALINSKE FORMULA                                                  SEDD2370
C                                                                       SEDD2380
  420 CALL KALIN                                                        SEDD2390
      GO TO 600                                                         SEDD2400
C                                                                       SEDD2410
C     MEYER-PETER AND MULLER FORMULA   (USES SIZE FRACTIONS)            SEDD2420
C                                                                       SEDD2430
  430 CALL MEYER                                                        SEDD2440
      GO TO 600                                                         SEDD2450
C                                                                       SEDD2460
C     ROTTNER FORMULA                                                   SEDD2470
C                                                                       SEDD2480
  440 CALL ROTTNER                                                      SEDD2490
      GO TO 600                                                         SEDD2500
C                                                                       SEDD2510
C     EINSTEIN BEDLOAD FORMULA   (USES SIZE FRACTIONS)                  SEDD2520
C                                                                       SEDD2530
  450 CALL EINS (2)                                                     SEDD2540
      GO TO 600                                                         SEDD2550
C                                                                       SEDD2560
C     TOFFALETI FORMULA - BEDLOAD PORTION   (USES SIZE FRACTIONS)       SEDD2570
C                                                                       SEDD2580
  460 CALL TOFF (2)                                                     SEDD2590
  600 CONTINUE                                                          SEDD2600
  610 WRITE (6,13)                                                      SEDD2610
  700 CONTINUE                                                          SEDD2620
      GO TO 1020                                                        SEDD2630
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 1000 WRITE (6,14) DFILE                                                SEDD2640
      GO TO 1020                                                        SEDD2650
 1010 WRITE (6,15) DFILE                                                SEDD2660
 1020 ENDFILE (6)                                                       SEDD2670
      CLOSE (5)                                                         SEDD2680
      CLOSE (6)                                                         SEDD2690
      CALL CLSCR(25)                                                    SEDD2700
      WRITE (1,16) OFILE                                                SEDD2710
      CALL CLSCR(5)                                                     SEDD2720
      CALL EXIT                                                         SEDD2730
      END                                                               SEDD2740


      SUBROUTINE PRFRAC (I)                                             PRFC  10
C                                                                       PRFC  20
C     PRINT DISCHARGES BY SIZE FRACTION                                 PRFC  30
C                                                                       PRFC  40
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,  PRFC  50
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U, PRFC  60
     2 UGSI,V,W,XNU,Y                                                   PRFC  70
    1 FORMAT (1H ,'          SIZE RANGE      FRACTION' / 1H ,'        IN MPRFC  80
     1ILLIMETERS     IN BED' )                                          PRFC  90
    2 FORMAT (1H ,6X,2F8.3,F10.3,13X,F9.2,F13.4)                        PRFC 100
C                                                                       PRFC 110
      IF (I.GT.0) GO TO 100                                             PRFC 120
      WRITE (6,1)                                                       PRFC 130
      RETURN                                                            PRFC 140
  100 WRITE (6,2) SIZELO(I),SIZEHI(I),PCT(I),CI,UGSI                    PRFC 150
      RETURN                                                            PRFC 160
      END                                                               PRFC 170


      SUBROUTINE CLSCR (N)                                              CLSC  10
C                                                                       CLSC  20
C     MOVE CURSOR DOWN N LINES                                          CLSC  30
C                                                                       CLSC  40
      DO 10 I=1,N                                                       CLSC  50
      WRITE (1,*) '          '                                          CLSC  60
   10 CONTINUE                                                          CLSC  70
      RETURN                                                            CLSC  80
      END                                                               CLSC  90


      SUBROUTINE FVEL (D,T,FV)                                          FVEL  10
C                                                                       FVEL  20
C     COMPUTE REPORT 12 SEDIMENT FALL VELOCITY, IN FT/SEC               FVEL  30
C                                                                       FVEL  40
C     INPUT DIAMETER IS IN FEET    TEMPERATURE IS IN DEG C              FVEL  50
C     MAX DIA IS 0.0328 FEET (10 MM)       MAX TEMP IS 40 DEG C         FVEL  60
C                                                                       FVEL  70
```

```
      DIMENSION AF(6,13),ZF(2)                                          FVEL  80
      DATA (AF(I,1),I=1,6)/.00001,.001,.0001,.0001,.0001,.0001/         FVEL  90
      DATA (AF(I,2),I=1,6)/.06,.24,.32,.4,.49,.57/                      FVEL 100
      DATA (AF(I,3),I=1,6)/.1,.6,.76,.92,1.1,1.26/                      FVEL 110
      DATA (AF(I,4),I=1,6)/.2,1.8,2.2,2.5,2.85,3.2/                     FVEL 120
      DATA (AF(I,5),I=1,6)/.4,4.6,5.3,5.8,6.3,6.7/                      FVEL 130
      DATA (AF(I,6),I=1,6)/.8,9.5,10.5,11.0,11.6,12/                    FVEL 140
      DATA (AF(I,7),I=1,6)/1.5,16.1,16.9,17.5,17.9,18.1/                FVEL 150
      DATA (AF(I,8),I=1,6)/2.0,19.9,20.3,20.7,21.1,21.5/                FVEL 160
      DATA (AF(I,9),I=1,6)/3.0,25.3,25.6,25.9,26.2,26.5/                FVEL 170
      DATA (AF(I,10),I=1,6)/7.0,39.5,39.5,39.5,39.5,39.5/               FVEL 180
      DATA (AF(I,11),I=1,6)/8.0,41.5,41.5,41.5,41.5,41.5/               FVEL 190
      DATA (AF(I,12),I=1,6)/9.0,43.5,43.5,43.5,43.5,43.5/               FVEL 200
      DATA (AF(I,13),I=1,6)/10.0,45.0,45.0,45.0,45.0,45.0/              FVEL 210
C                                                                       FVEL 220
      DFV=D*304.8                                                       FVEL 230
      SF=T/10.                                                          FVEL 240
      KT=INT(SF)+1                                                      FVEL 250
      PT=SF-FLOAT(KT)+1.                                                FVEL 260
      DL=ALOG10(DFV)                                                    FVEL 270
      DO 30 I=1,11                                                      FVEL 280
      IF (DFV.LE.AF(1,I)) GO TO 40                                      FVEL 290
   30 CONTINUE                                                          FVEL 300
   40 I=I-1                                                             FVEL 310
      CF=ALOG10(AF(1,I))                                                FVEL 320
      EF=ALOG10(AF(1,I+1))                                              FVEL 330
      PD=(DL-CF)/(EF-CF)                                                FVEL 340
      DO 50 L=1,2                                                       FVEL 350
      K=L+KT                                                            FVEL 360
      ZF(L)=(1.-PD)*ALOG10(AF(K,I))+PD*ALOG10(AF(K,I+1))                FVEL 370
   50 CONTINUE                                                          FVEL 380
      RF=(1.-PT)*ZF(1)+PT*ZF(2)                                         FVEL 390
      FV=10**RF/30.48                                                   FVEL 400
      RETURN                                                            FVEL 410
      END                                                               FVEL 420


      SUBROUTINE LASN                                                   LAUR  10
C                                                                       LAUR  20
C     LAURSEN FORMULA                                                   LAUR  30
C                                                                       LAUR  40
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,  LAUR  50
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U, LAUR  60
     2 UGSI,V,W,XNU,Y                                                   LAUR  70
    1 FORMAT (1H ,'LAURSEN',38X,'SIZE FRACTION DATA NOT GIVEN')         LAUR  80
    2 FORMAT (1H ,'LAURSEN')                                            LAUR  90
    3 FORMAT (1H ,'LAURSEN',38X,F9.2,F13.4,F12.2)                       LAUR 100
    4 FORMAT (1H ,7X,'TOTAL',33X,F9.2,F13.4,F12.2)                      LAUR 110
C                                                                       LAUR 120
      IF (SUMP.GT.0) GO TO 100                                          LAUR 130
      WRITE (6,1)                                                       LAUR 140
      RETURN                                                            LAUR 150
```

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100 IF (LSF.EQ.0) GO TO 110                                                    LAUR 160
    WRITE (6,2)                                                                LAUR 170
    CALL PRFRAC(0)                                                             LAUR 180
110 C=0                                                                        LAUR 190
    UGS=0                                                                      LAUR 200
    DELTA=11.6*XNU/U                                                           LAUR 210
    DO 200 I=2,11                                                              LAUR 220
    IF (PCT(I).LE.0) GO TO 200                                                 LAUR 230
    COMP1=6.*XNU                                                               LAUR 240
    FVI=((36.064*DFT(I)**3+COMP1**2)**.5-COMP1)/DFT(I)                         LAUR 250
    RV=U/FVI                                                                   LAUR 260
    RVL=LOG10(RV)                                                              LAUR 270
    IF (RV.GT.0.3) GO TO 120                                                   LAUR 280
    FV=10.718*RV**.243                                                         LAUR 290
    GO TO 160                                                                  LAUR 300
120 IF (RV.GT.3) GO TO 130                                                     LAUR 310
    FV=10.**(.855*RVL+.62*RVL*RVL+1.2)                                         LAUR 320
    GO TO 160                                                                  LAUR 330
130 IF (RV.GT.20.) GO TO 140                                                   LAUR 340
    FV=4.773*RV**2.304                                                         LAUR 350
    GO TO 160                                                                  LAUR 360
140 IF (RV.GT.200.) GO TO 150                                                  LAUR 370
    FV=10.**(3.764*RVL-.803*RVL*RVL+.147)                                      LAUR 380
    GO TO 160                                                                  LAUR 390
150 FV=9680.5*RV**.2531                                                        LAUR 400
160 RY=DFT(I)/DELTA                                                            LAUR 410
    IF (RY.GT.0.03) GO TO 170                                                  LAUR 420
    YC=.16                                                                     LAUR 430
    GO TO 190                                                                  LAUR 440
170 IF (RY.GT.0.1) GO TO 180                                                   LAUR 450
    YC=.08                                                                     LAUR 460
    GO TO 190                                                                  LAUR 470
180 YC=.04                                                                     LAUR 480
190 F1=(DFT(I)/Y)**1.1667                                                      LAUR 490
    F2=V*V/(58.*YC*DFT(I)*(SG-1)*G)                                            LAUR 500
    F3=(DF50/Y)**.3333                                                         LAUR 510
    CI=10000*PCT(I)*F1*(F2*F3-1)*FV                                            LAUR 520
    IF (CI.LT.0.) CI=0                                                         LAUR 530
    C=C+CI                                                                     LAUR 540
    UGSI=.0000625*CI*Y*V                                                       LAUR 550
    UGS=UGS+UGSI                                                               LAUR 560
    IF (LSF.GT.0) CALL PRFRAC(I)                                               LAUR 570
200 CONTINUE                                                                   LAUR 580
    GS=UGS*43.2*W                                                              LAUR 590
    IF (LSF.GT.0) GO TO 210                                                    LAUR 600
    WRITE (6,3) C,UGS,GS                                                       LAUR 610
    RETURN                                                                     LAUR 620
210 WRITE (6,4) C,UGS,GS                                                       LAUR 630
    RETURN                                                                     LAUR 640
    END                                                                        LAUR 650
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      SUBROUTINE ENG                                                    ENGD  10
                                                                        ENGD  20
C                                                                       ENGD  30
C     ENGELUND AND HANSEN FORMULA                                       ENGD  40
C                                                                       ENGD  50
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,  ENGD  60
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U, ENGD  70
     2 UGSI,V,W,XNU,Y                                                   ENGD  80
    1 FORMAT (1H ,'ENGELUND & HANSEN',28X,F9.2,F13.4,F12.2)             ENGD  90
C                                                                       ENGD 100
      UGS=.05*GMS*V*V*Y**1.5*S**1.5/(DF50*G**.5*(SG-1)**2)              ENGD 110
      C=16000*UGS/(Y*V)                                                 ENGD 120
      GS=UGS*43.2*W                                                     ENGD 130
      WRITE (6,1) C,UGS,GS                                              ENGD 140
      RETURN                                                            ENGD 150
      END


      SUBROUTINE COLBY                                                  COBY  10
                                                                        COBY  20
C                                                                       COBY  30
C     COLBY FORMULA                                                     COBY  40
C                                                                       COBY  50
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,  COBY  60
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U, COBY  70
     2 UGSI,V,W,XNU,Y                                                   COBY  80
      DIMENSION CY(7,7),CF(5)                                           COBY  90
    1 FORMAT (1H ,'COLBY',40X,'D50 LT 0.1 OR D50 GT 0.8')               COBY 100
    2 FORMAT (1H ,'COLBY',40X,F9.2,F13.4,F12.2)                         COBY 110
      DATA CF/.64,1,1,.88,.2/                                           COBY 120
      DATA (CY(1,I),I=1,7)/.1,.2,.3,.4,.8,0,0/                          COBY 130
      DATA (CY(2,I),I=1,7)/.61,.48,.3,.3,.3,0,0/                        COBY 140
      DATA (CY(3,I),I=1,7)/1.453,1.329,1.4,1.26,1.099,0,0/              COBY 150
      DATA (CY(4,I),I=1,7)/.01,5,10,15.6,20,30,40/                      COBY 160
      DATA (CY(5,I),I=1,7)/.1057,.0845,.0469,0,-.0277,-.0654,-.1155/    COBY 170
      DATA (CY(6,I),I=1,7)/.0735,.0166,.0014,0,-.0164,-.061,-.0763/     COBY 180
      DATA (CY(7,I),I=1,7)/.0118,.0202,.0135,0,0,0,0/                   COBY 190
C                                                                       COBY 200
      IF (D50.GE.0.1.AND.D50.LE.0.8) GO TO 10                           COBY 210
      WRITE (6,1)                                                       COBY 220
      RETURN                                                            COBY 230
   10 VC=.4673*Y**.1*D50**.333                                          COBY 240
      DIFF=V*.3048-VC                                                   COBY 250
      B=2.5                                                             COBY 260
      IF (DIFF.GE.1.0) B=1.453*D50**(-.138)                             COBY 270
      X=LOG10(Y)                                                        COBY 280
      N=0                                                               COBY 290
   20 N=N+1                                                             COBY 300
      IF (TEMP.GT.CY(4,N)) GO TO 20                                     COBY 310
      F1=CY(5,N-1)+CY(6,N-1)*X+CY(7,N-1)*X*X                            COBY 320
      F2=CY(5,N)+CY(6,N)*X+CY(7,N)*X*X                                  COBY 330
      AF=F1+(F2-F1)*(LOG10(TEMP)-LOG10(CY(4,N-1)))/(LOG10(CY(4,N))-     COBY 340
     1 LOG10(CY(4,N-1)))                                                COBY 350
      AF=10**(AF)
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```
      N=0                                                                    COBY 360
   30 N=N+1                                                                  COBY 370
      IF (D50.GT.CY(1,N)) GO TO 30                                           COBY 380
      A=CY(3,N-1)*Y**(CY(2,N-1))                                             COBY 390
      F1=A*DIFF**B*(1+(AF-1)*CF(N-1))*.672                                   COBY 400
      A=CY(3,N)*Y**(CY(2,N))                                                 COBY 410
      F2=A*DIFF**B*(1+(AF-1)*CF(N))*.672                                     COBY 420
      UGS=LOG10(F1)+(LOG10(F2)-LOG10(F1))*(LOG10(D50)-LOG10(CY(1,N-1)))      COBY 430
     1 /(LOG10(CY(1,N))-LOG10(CY(1,N-1)))                                    COBY 440
      UGS=10**UGS                                                            COBY 450
      C=16000*UGS/(Y*V)                                                      COBY 460
      GS=UGS*43.2*W                                                          COBY 470
      WRITE (6,2) C,UGS,GS                                                   COBY 480
      RETURN                                                                 COBY 490
      END                                                                    COBY 500


      SUBROUTINE ACK                                                         ACKS  10
C                                                                            ACKS  20
C     ACKERS AND WHITE FORMULA                                               ACKS  30
C                                                                            ACKS  40
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,       ACKS  50
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,      ACKS  60
     2 UGSI,V,W,XNU,Y                                                        ACKS  70
    1 FORMAT (1H ,'ACKERS & WHITE  (USING D35)',18X,'D35 NOT GIVEN')         ACKS  80
    2 FORMAT (1H ,'ACKERS & WHITE  (USING D50)',18X,F9.2,F13.4,F12.2)        ACKS  90
    3 FORMAT (1H ,'ACKERS & WHITE  (USING D35 = ',F5.3,' MM )',6X,F9.2,      ACKS 100
     1 F13.4,F12.2)                                                          ACKS 110
    4 FORMAT (1H ,'ACKERS & WHITE  (USING D50)',18X,'COMPUTED CONCENTRATA    ACKS 120
     1ION LESS THAN ZERO')                                                   ACKS 130
    5 FORMAT (1H ,'ACKERS & WHITE  (USING D35)',18X,'COMPUTED CONCENTRATA    ACKS 140
     1ION LESS THAN ZERO')                                                   ACKS 150
      D=DF50                                                                 ACKS 160
      IF (IOS.EQ.4) GO TO 110                                                ACKS 170
      IF (DF35.GT.0.) GO TO 100                                              ACKS 180
      WRITE (6,1)                                                            ACKS 190
      RETURN                                                                 ACKS 200
  100 D=DF35                                                                 ACKS 210
  110 DGR=D*((G*(SG-1)/(XNU*XNU))**.3333)                                    ACKS 220
      P=LOG10(DGR)                                                           ACKS 230
      IF (DGR.GT.60) GO TO 120                                               ACKS 240
      AN=1-.56*P                                                             ACKS 250
      AA=.23/SQRT(DGR)+.14                                                   ACKS 260
      AM=9.66/DGR+1.34                                                       ACKS 270
      CA=2.86*P-P*P-3.53                                                     ACKS 280
      CA=10**CA                                                              ACKS 290
      GO TO 130                                                              ACKS 300
  120 AN=0                                                                   ACKS 310
      AA=.17                                                                 ACKS 320
      AM=1.5                                                                 ACKS 330
      CA=.025                                                                ACKS 340
  130 F1=U**AN/(SQRT(G*D*(SG-1)))                                            ACKS 350
```

```
      F2=(V/(SQRT(G)*LOG10(10.*Y/D)))**(1-AN)                          ACKS 360
      F3=F1*F2/AA-1                                                    ACKS 370
      IF (F3.LE.0) GO TO 160                                           ACKS 380
      GGR=CA*F3**AM                                                    ACKS 390
      C=(GGR*D*SG*(V/U)**AN)/Y                                         ACKS 400
      C=C*10**6.                                                       ACKS 410
      UGS=.0000625*C*Y*V                                               ACKS 420
      GS=UGS*43.2*W                                                    ACKS 430
  140 IF (IOS.EQ.5) GO TO 150                                          ACKS 440
      WRITE (6,2) C,UGS,GS                                             ACKS 450
      RETURN                                                           ACKS 460
  150 WRITE (6,3) D35,C,UGS,GS                                         ACKS 470
      RETURN                                                           ACKS 480
  160 IF (IOS.EQ.5) GO TO 170                                          ACKS 490
      WRITE (6,4)                                                      ACKS 500
      RETURN                                                           ACKS 510
  170 WRITE (6,5)                                                      ACKS 520
      RETURN                                                           ACKS 530
      END                                                              ACKS 540


      SUBROUTINE YAG50                                                 YG50  10
C                                                                      YG50  20
C     YANG SAND & GRAVEL FORMULAS USING D50                            YG50  30
C                                                                      YG50  40
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G, YG50  50
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U, YG50  60
     2 UGSI,V,W,XNU,Y                                                  YG50  70
    1 FORMAT (1H ,'YANG SAND  (USING D50)',23X,F9.2,F13.4,F12.2)       YG50  80
    2 FORMAT (1H ,'YANG GRAVEL  (USING D50)'21X,F9.2,F13.4,F12.2)      YG50  90
C                                                                      YG50 100
      FV=FV50                                                          YG50 110
      IF (DF50.GE.0.0328) GO TO 100                                    YG50 120
      CALL FVEL (DF50,TEMP,FV)                                         YG50 130
  100 R=U*DF50/XNU                                                     YG50 140
      F1=2.05                                                          YG50 150
      IF (R.GE.70.) GO TO 110                                          YG50 160
      F1=.66+2.5/(LOG10(R)-.06)                                        YG50 170
  110 F2=LOG10(FV*DF50/XNU)                                            YG50 180
      F3=LOG10(U/FV)                                                   YG50 190
      C=0                                                              YG50 200
      F4=V*S/FV-F1*S                                                   YG50 210
      IF (F4.LE.0.) GO TO 140                                          YG50 220
      IF (IOS.EQ.8) GO TO 120                                          YG50 230
      C=5.435-.286*F2-.457*F3+(1.799-.409*F2-.314*F3)*LOG10(F4)        YG50 240
      GO TO 130                                                        YG50 250
  120 C=6.681-.633*F2-4.816*F3+(2.784-.305*F2-.282*F3)*LOG10(F4)       YG50 260
  130 C=10.**C                                                         YG50 270
  140 UGS=.0000625*C*Y*V                                               YG50 280
      GS=UGS*43.2*W                                                    YG50 290
      IF (IOS.EQ.8) GO TO 150                                          YG50 300
      WRITE (6,1) C,UGS,GS                                             YG50 310
```

```
      RETURN                                                            YG50 320
  150 WRITE (6,2) C,UGS,GS                                              YG50 330
      RETURN                                                            YG50 340
      END                                                               YG50 350


      SUBROUTINE YAGFR                                                  YGFR  10
C                                                                       YGFR  20
C     YANG SAND & GRAVEL FORMULAS USING SIZE FRACTIONS                  YGFR  30
C                                                                       YGFR  40
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,  YGFR  50
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U, YGFR  60
     2 UGSI,V,W,XNU,Y                                                   YGFR  70
    1 FORMAT (1H ,'YANG SAND  (USING SIZE FRACTIONS)',12X,'SIZE FRACTIONYGFR  80
     1 DATA NOT GIVEN' )                                                YGFR  90
    2 FORMAT (1H ,'YANG GRAVEL  (USING SIZE FRACTIONS)',10X,'SIZE FRACTIYGFR 100
     1ON DATA NOT GIVEN' )                                              YGFR 110
    3 FORMAT (1H ,'YANG MIXTURE  (USING SIZE FRACTIONS)',9X,'SIZE FRACTIYGFR 120
     1ON DATA NOT GIVEN' )                                              YGFR 130
    4 FORMAT (1H ,'YANG SAND  (USING SIZE FRACTIONS)' )                 YGFR 140
    5 FORMAT (1H ,'YANG GRAVEL  (USING SIZE FRACTIONS)' )               YGFR 150
    6 FORMAT (1H ,'YANG MIXTURE  (USING SIZE FRACTIONS)' )              YGFR 160
    7 FORMAT (1H ,'YANG SAND  (USING SIZE FRACTIONS)',12X,F9.2,F13.4,   YGFR 170
     1 F12.2 )                                                          YGFR 180
    8 FORMAT (1H ,'YANG GRAVEL  (USING SIZE FRACTIONS)',10X,F9.2,F13.4, YGFR 190
     1 F12.2 )                                                          YGFR 200
    9 FORMAT (1H ,'YANG MIXTURE  (USING SIZE FRACTIONS)',9X,F9.2,F13.4, YGFR 210
     1 F12.2 )                                                          YGFR 220
   10 FORMAT (1H ,7X,'TOTAL',33X,F9.2,F13.4,F12.2 )                     YGFR 230
C                                                                       YGFR 240
      IF (SUMP.GT.0.) GO TO 130                                         YGFR 250
      IF (IOS-9) 100,110,120                                            YGFR 260
  100 WRITE (6,1)                                                       YGFR 270
      RETURN                                                            YGFR 280
  110 WRITE (6,2)                                                       YGFR 290
      RETURN                                                            YGFR 300
  120 WRITE (6,3)                                                       YGFR 310
      RETURN                                                            YGFR 320
  130 IF (LSF.EQ.0) GO TO 180                                           YGFR 330
      IF (IOS-9) 140,150,160                                            YGFR 340
  140 WRITE (6,4)                                                       YGFR 350
      GO TO 170                                                         YGFR 360
  150 WRITE (6,5)                                                       YGFR 370
      GOTO 170                                                          YGFR 380
  160 WRITE (6,6)                                                       YGFR 390
  170 CALL PRFRAC(0)                                                    YGFR 400
  180 C=0                                                               YGFR 410
      UGS=0                                                             YGFR 420
      DO 250 I=2,11                                                     YGFR 430
      IF (PCT(I).LE.0) GO TO 250                                        YGFR 440
      D=DFT(I)                                                          YGFR 450
      IF (D.LE.0.0328) GO TO 190                                        YGFR 460
```

```
      COMP1=6.*XNU                                                    YGFR 470
      FV=((36.064*D**3+COMP1**2)**.5-COMP1)/D                         YGFR 480
      GO TO 200                                                       YGFR 490
  190 CALL FVEL (D,TEMP,FV)                                           YGFR 500
  200 R=U*D/XNU                                                       YGFR 510
      F1=2.05                                                         YGFR 520
      IF (R.GE.70.) GO TO 210                                         YGFR 530
      F1=.66+2.5/(LOG10(R)-.06)                                       YGFR 540
  210 F2=LOG10(FV*D/XNU)                                              YGFR 550
      F3=LOG10(U/FV)                                                  YGFR 560
      CI=0                                                            YGFR 570
      F4=V*S/FV-F1*S                                                  YGFR 580
      IF (F4.LE.0) GO TO 240                                          YGFR 590
      IF (IOS.EQ.9) GO TO 220                                         YGFR 600
      IF (IOS.EQ.10.AND.I.GT.6) GO TO 220                             YGFR 610
      CI=5.435-.286*F2-.457*F3+(1.799-.409*F2-.314*F3)*LOG10(F4)      YGFR 620
      GO TO 230                                                       YGFR 630
  220 CI=6.681-.633*F2-4.816*F3+(2.784-.305*F2-.282*F3)*LOG10(F4)     YGFR 640
  230 CI=10**CI*PCT(I)                                                YGFR 650
  240 C=C+CI                                                          YGFR 660
      UGSI=.0000625*CI*Y*V                                            YGFR 670
      UGS=UGS+UGSI                                                    YGFR 680
      IF (LSF.GT.0) CALL PRFRAC(I)                                    YGFR 690
  250 CONTINUE                                                        YGFR 700
      GS=UGS*43.2*W                                                   YGFR 710
      IF (LSF.GT.0) GO TO 290                                         YGFR 720
      IF (IOS-9) 260,270,280                                          YGFR 730
  260 WRITE (6,7) C,UGS,GS                                            YGFR 740
      RETURN                                                          YGFR 750
  270 WRITE (6,8) C,UGS,GS                                            YGFR 760
      RETURN                                                          YGFR 770
  280 WRITE (6,9) C,UGS,GS                                            YGFR 780
      RETURN                                                          YGFR 790
  290 WRITE (6,10) C,UGS,GS                                           YGFR 800
      RETURN                                                          YGFR 810
      END                                                             YGFR 820



      SUBROUTINE SCHOK                                                SCHK  10
C                                                                     SCHK  20
C     SCHOKLITSCH FORMULA                                             SCHK  30
C                                                                     SCHK  40
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,SCHK  50
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,SCHK  60
     2 UGSI,V,W,XNU,Y                                                 SCHK  70
    1 FORMAT (1H ,'SCHOKLITSCH',34X,'SIZE FRACTION DATA NOT GIVEN')   SCHK  80
    2 FORMAT (1H ,'SCHOKLITSCH')                                      SCHK  90
    3 FORMAT (1H ,'SCHOKLITSCH',34X,F9.2,F13.4,F12.2)                 SCHK 100
    4 FORMAT (1H ,7X,'TOTAL',33X,F9.2,F13.4,F12.2)                    SCHK 110
C                                                                     SCHK 120
      IF (SUMP.GT.0) GO TO 100                                        SCHK 130
      WRITE (6,1)                                                     SCHK 140
```

```
      RETURN                                                            SCHK 150
  100 IF (LSF.EQ.0) GO TO 110                                           SCHK 160
      WRITE (6,2)                                                       SCHK 170
      CALL PRFRAC(0)                                                    SCHK 180
  110 C=0                                                               SCHK 190
      UGS=0                                                             SCHK 200
      F1=25.*S**1.5*V*Y                                                 SCHK 210
      F2=1.6*S**.17                                                     SCHK 220
      DO 130 I=1,11                                                     SCHK 230
      IF (PCT(I).LE.0) GO TO 130                                        SCHK 240
      CI=0                                                              SCHK 250
      UGSI=0                                                            SCHK 260
      F3=DFT(I)**.5                                                     SCHK 270
      X=F1/F3-F2*F3                                                     SCHK 280
      IF (X.LE.0) GO TO 120                                             SCHK 290
      UGSI=X*PCT(I)                                                     SCHK 300
  120 UGS=UGS+UGSI                                                      SCHK 310
      CI=16000*UGSI/(Y*V)                                               SCHK 320
      C=C+CI                                                            SCHK 330
      IF (LSF.GT.0) CALL PRFRAC(I)                                      SCHK 340
  130 CONTINUE                                                          SCHK 350
      GS=UGS*43.2*W                                                     SCHK 360
      IF (LSF.GT.0) GO TO 210                                           SCHK 370
      WRITE (6,3) C,UGS,GS                                              SCHK 380
      RETURN                                                            SCHK 390
  210 WRITE (6,4) C,UGS,GS                                              SCHK 400
      RETURN                                                            SCHK 410
      END                                                               SCHK 420
```

```
      SUBROUTINE KALIN                                                  KALN  10
C                                                                       KALN  20
C     KALINSKE FORMULA                                                  KALN  30
C                                                                       KALN  40
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,  KALN  50
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U, KALN  60
     2 UGSI,V,W,XNU,Y                                                   KALN  70
      DIMENSION RAT(11),A(6)                                            KALN  80
    1 FORMAT (1H ,'KALINSKE',37X,'SIZE FRACTION DATA NOT GIVEN')        KALN  90
    2 FORMAT (1H ,'KALINSKE')                                           KALN 100
    3 FORMAT (1H ,'KALINSKE',37X,F9.2,F13.4,F12.2)                      KALN 110
    4 FORMAT (1H ,7X,'TOTAL',33X,F9.2,F13.4,F12.2)                      KALN 120
      DATA A/-.068,-1.1328,.94,-1.206,.567,-.0975/                      KALN 130
C                                                                       KALN 140
      IF (SUMP.GT.0) GO TO 100                                          KALN 150
      WRITE (6,1)                                                       KALN 160
      RETURN                                                            KALN 170
  100 IF (LSF.EQ.0) GO TO 110                                           KALN 180
      WRITE (6,2)                                                       KALN 190
      CALL PRFRAC(0)                                                    KALN 200
  110 S1=0                                                              KALN 210
      DO 120 I=1,11                                                     KALN 220
```

```
      RAT(I)=PCT(I)/DFT(I)                                                  KALN 230
      S1=S1+RAT(I)                                                          KALN 240
  120 CONTINUE                                                              KALN 250
      C=0                                                                   KALN 260
      UGS=0                                                                 KALN 270
      T0=62.4*Y*S                                                           KALN 280
      F1=25.28*T0**.5/S1                                                    KALN 290
      DO 130 I=1,11                                                         KALN 300
      IF (PCT(I).LE.0) GO TO 130                                            KALN 310
      T1=12.*DFT(I)                                                         KALN 320
      X=T1/T0                                                               KALN 330
      F2=A(1)+A(2)*X+A(3)*X**2+A(4)*X**3+A(5)*X**4+A(6)*X**5                KALN 340
      F2=10.**(F2)                                                          KALN 350
      UGSI=F1*T1*RAT(I)*F2                                                  KALN 360
      UGS=UGS+UGSI                                                          KALN 370
      CI=16000*UGSI/(Y*V)                                                   KALN 380
      C=C+CI                                                                KALN 390
      IF (LSF.GT.0) CALL PRFRAC(I)                                          KALN 400
  130 CONTINUE                                                              KALN 410
      GS=UGS*43.2*W                                                         KALN 420
      IF (LSF.GT.0) GO TO 210                                               KALN 430
      WRITE (6,3) C,UGS,GS                                                  KALN 440
      RETURN                                                                KALN 450
  210 WRITE (6,4) C,UGS,GS                                                  KALN 460
      RETURN                                                                KALN 470
      END                                                                   KALN 480


      SUBROUTINE MEYER                                                      MEYR  10
C                                                                           MEYR  20
C     MEYER-PETER AND MULLER FORMULA                                        MEYR  30
C                                                                           MEYR  40
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,      MEYR  50
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,     MEYR  60
     2 UGSI,V,W,XNU,Y                                                       MEYR  70
      CHARACTER*45 LABEL(3)                                                 MEYR  80
    1 FORMAT (1H ,'MEYER-PETER & MULLER',25X,'SIZE FRACTION DATA NOT GIVMEYR  90
     1EN')                                                                  MEYR 100
    2 FORMAT (1H ,'MEYER-PETER AND MULLER   ',A45)                          MEYR 110
    3 FORMAT (1H ,'MEYER-PETER & MULLER')                                   MEYR 120
    4 FORMAT (1H ,'MEYER-PETER & MULLER      BOT WIDTH =',F8.2 )            MEYR 130
    5 FORMAT (1H ,2X,A45 / 1H ,'  D90 =',F7.3,' MM    M-P DM =',F7.3 )      MEYR 140
    6 FORMAT (1H ,'  NW =',F7.3,'    NM =',F7.3 )                           MEYR 150
    7 FORMAT (1H ,'  QS/Q =',F7.3,'    NS =',F8.4,14X,F9.2,F13.4,F12.2)    MEYR 160
      DATA LABEL/'QS/Q=1 AND NS=STRICKLER ROUGHNESS','RECTANGULAR CHANNEMEYR 170
     1L AND COMPUTE NS AND QS/Q','TRAPEZOIDAL CHANNEL AND COMPUTE NS ANDMEYR 180
     2 QS/Q'/                                                               MEYR 190
C                                                                           MEYR 200
      IF (SUMP.GT.0) GO TO 100                                              MEYR 210
      WRITE (6,1)                                                           MEYR 220
      RETURN                                                                MEYR 230
  100 DM=0.0                                                                MEYR 240
```

```
      DO 110 I=1,11                                                    MEYR 250
      DM=DM+PCT(I)*DIA(I)                                              MEYR 260
  110 CONTINUE                                                         MEYR 270
      UGS=0.0                                                          MEYR 280
      IF (IOS.GT.3) GO TO 120                                          MEYR 290
      QSQ=1.0                                                          MEYR 300
      RNS=1.486*Y**.667*S**.5/V                                        MEYR 310
      GO TO 150                                                        MEYR 320
  120 WRITE (1,2) LABEL(IOS-2)                                         MEYR 330
      WRITE (1,*) 'ENTER MANNING"S N FOR CHANNEL SIDES (NW)'           MEYR 340
      READ (1,*) RNW                                                   MEYR 350
      WRITE (1,*) 'ENTER MANNING"S N FOR TOTAL STREAM  (NM)'           MEYR 360
      READ (1,*) RNM                                                   MEYR 370
      IF (IOS.EQ.5) GO TO 130                                          MEYR 380
      WRITE (1,*) '          '                                         MEYR 390
      F1=2.*Y/W                                                        MEYR 400
      GO TO 140                                                        MEYR 410
  130 WRITE (1,*) 'ENTER BOTTOM WIDTH, IN FEET'                        MEYR 420
      READ (1,*) BW                                                    MEYR 430
      WRITE (1,*) '          '                                         MEYR 440
      F2=(W-BW)/2./Y                                                   MEYR 450
      F1=2*Y*(1.+F2**2)**.5/BW                                         MEYR 460
  140 RNS=RNM*(1.+F1*(1.-(RNW/RNM)**1.5))**.667                        MEYR 470
      QSQ=1./(1.+F1*(RNW/RNS)**1.5)                                    MEYR 480
  150 UGS=0.0                                                          MEYR 490
      X=.368*QSQ*(D90**.1667/RNS)**1.5*Y*S-.0698*DM                    MEYR 500
      IF (X.GT.0.0) UGS=X**1.5                                         MEYR 510
      C=16000*UGS/(Y*V)                                                MEYR 520
      GS=UGS*43.2*W                                                    MEYR 530
      IF (IOS.EQ.5) GO TO 160                                          MEYR 540
      WRITE (6,3)                                                      MEYR 550
      GO TO 170                                                        MEYR 560
  160 WRITE (6,4) BW                                                   MEYR 570
  170 WRITE (6,5) LABEL(IOS-2),D90,DM                                  MEYR 580
      IF (IOS.GT.3) WRITE (6,6) RNW,RNM                                MEYR 590
      WRITE (6,7) QSQ,RNS,C,UGS,GS                                     MEYR 600
      RETURN                                                           MEYR 610
      END                                                              MEYR 620


C     SUBROUTINE ROTTNER                                               ROTT  10
C                                                                      ROTT  20
C     ROTTNER FORMULA                                                  ROTT  30
C                                                                      ROTT  40
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G, ROTT  50
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U, ROTT  60
     2 UGSI,V,W,XNU,Y                                                 ROTT  70
    1 FORMAT (1H ,'ROTTNER',38X,F9.2,F13.4,F12.2)                      ROTT  80
C                                                                      ROTT  90
      R=(DF50/Y)**.667                                                 ROTT 100
      F1=V/(7.286*Y**.5)                                               ROTT 110
      F2=-.667*R+.14                                                   ROTT 120
```

```
      UGS=1204.8*Y**1.5*(F1*F2-.778*R)**3                                ROTT 130
      C=16000*UGS/(Y*V)                                                  ROTT 140
      GS=UGS*43.2*W                                                      ROTT 150
      WRITE (6,1) C,UGS,GS                                               ROTT 160
      RETURN                                                             ROTT 170
      END                                                                ROTT 180


       SUBROUTINE EINS (NLD)                                             EINS  10
C                                                                        EINS  20
C      EINSTEIN FORMULA                                                  EINS  30
C                                                                        EINS  40
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,   EINS  50
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,  EINS  60
     2 UGSI,V,W,XNU,Y                                                    EINS  70
    1 FORMAT (1H ,'EINSTEIN',37X,'SIZE FRACTION DATA NOT GIVEN' )        EINS  80
    2 FORMAT (1H ,'EINSTEIN' )                                           EINS  90
    3 FORMAT (1H ,'EINSTEIN' / 1H ,'  D35 =',F7.3,' MM    D65 =',F7.3,  EINS 100
     1 ' MM' )                                                           EINS 110
    4 FORMAT (1H ,'  D35 =',F7.3,' MM    D65 =',F7.3,' MM',9X,F9.2,     EINS 120
     1 F13.4,F12.2)                                                      EINS 130
    5 FORMAT (1H ,7X,'TOTAL',33X,F9.2,F13.4,F12.2)                       EINS 140
C                                                                        EINS 150
      IF (SUMP.GT.0) GO TO 100                                           EINS 160
      WRITE (6,1)                                                        EINS 170
      RETURN                                                             EINS 180
  100 IF (LSF.GT.0) GO TO 110                                            EINS 190
      WRITE (6,2)                                                        EINS 200
      GO TO 120                                                          EINS 205
  110 WRITE (6,3) D35,D65                                                EINS 210
      CALL PRFRAC(0)                                                     EINS 220
  120 RB=Y                                                               EINS 230
      C=0                                                                EINS 240
      UGS=0                                                              EINS 250
      RBP=(V*DF65**.1667/(7.66*(G*S)**.5))**1.5                          EINS 260
      RBPP=RB-RBP                                                        EINS 270
      SVP=(G*RBP*S)**.5                                                  EINS 280
      DELTA=11.6*XNU/SVP                                                 EINS 290
      X9=DF65/DELTA                                                      EINS 300
      CALL FIG4 (X9,XR)                                                  EINS 310
      DELT=DF65/XR                                                       EINS 320
      COMP1=DELT/DELTA                                                   EINS 330
      IF (COMP1.LT.1.8) GO TO 130                                        EINS 340
      CAPX=.77*DELT                                                      EINS 350
      GO TO 140                                                          EINS 360
  130 CAPX=1.39*DELTA                                                    EINS 370
  140 CALL FIG8 (X9,CAPY)                                                EINS 380
      BETAX=ALOG10(10.6*CAPX/DELT)                                       EINS 390
      PVALUE=2.3026*ALOG10(30.2*XR*RB/DF65)                              EINS 400
      COMP1=6*XNU                                                        EINS 410
      DO 200 I=1,11                                                      EINS 420
      IF (PCT(I).LE.0) GO TO 200                                         EINS 430
```

```
      X9=DFT(I)/CAPX                                                    EINS 440
      CALL FIG7 (X9,XI)                                                 EINS 450
      PSIS=XI*CAPY*(1.025/BETAX)**2*(1.65*DFT(I)/(RBP*S))               EINS 460
      CALL FIG10 (PSIS,PHI)                                             EINS 470
      UNITBD=1200*PHI*DFT(I)**1.5*PCT(I)                                EINS 480
      UGSI=UNITBD                                                       EINS 490
      IF (NLD.EQ.2) GO TO 150                                           EINS 500
      FVI=((36.064*DFT(I)**3+COMP1**2)**.5-COMP1)/DFT(I)                EINS 510
      ZC=FVI/(.4*SVP)                                                   EINS 520
      AVAL=2.*DFT(I)/RB                                                 EINS 530
      VALI1=0.0                                                         EINS 540
      VALI2=0.0                                                         EINS 550
      CALL POWER (AVAL,ZC,VALI1,VALI2)                                  EINS 560
      UGSI=UNITBD*(PVALUE*VALI1+VALI2+1.0)                              EINS 570
  150 UGS=UGS+UGSI                                                      EINS 580
      CI=16000*UGSI/(Y*V)                                               EINS 590
      C=C+CI                                                            EINS 600
      IF (LSF.GT.0) CALL PRFRAC(I)                                      EINS 610
  200 CONTINUE                                                          EINS 620
      GS=UGS*43.2*W                                                     EINS 630
      IF (LSF.GT.0) GO TO 210                                           EINS 640
      WRITE (6,4) D35,D65,C,UGS,GS                                      EINS 650
      RETURN                                                            EINS 660
  210 WRITE (6,5) C,UGS,GS                                              EINS 670
      RETURN                                                            EINS 680
      END                                                               EINS 690


      SUBROUTINE FIG4 (X,Y)                                             FIG4  10
C                                                                       FIG4  20
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIGURE 4 WHERE:            FIG4  30
C                    X = F (KS / DELTA)                                 FIG4  40
C                                                                       FIG4  50
      DIMENSION FX(8),FA(8),FB(8)                                       FIG4  60
      DATA FX /0.5,0.65,0.9,1.15,1.4,3.2,5.0,8.4/                       FIG4  70
      DATA FA /1.9,1.75,1.62,1.61,1.63,1.72,1.42,1.25/                  FIG4  80
      DATA FB /1.72,1.23,0.57,0.0,-0.47,-1.11,-0.52,-0.27/              FIG4  90
      I=0                                                               FIG4 100
      Y=0.4                                                             FIG4 110
      IF (X.LT.0.135) RETURN                                            FIG4 120
      IF (X.LT.8.4) GO TO 100                                           FIG4 130
      Y=1.0                                                             FIG4 140
      RETURN                                                            FIG4 150
  100 I=I+1                                                             FIG4 160
      IF (X.GT.FX(I)) GO TO 100                                         FIG4 170
      Y=FB(I)*ALOG10(X)+FA(I)                                           FIG4 180
      RETURN                                                            FIG4 190
      END                                                               FIG4 200


      SUBROUTINE FIG7 (X,Y)                                             FIG7  10
```

```
C                                                                       FIG7  20
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIGURE 7 WHERE:            FIG7  30
C                     XI = F(D/X)                                       FIG7  40
C                                                                       FIG7  50
      DIMENSION FX(6),FA(6),FB(6)                                       FIG7  60
      DATA FX /0.2,0.4,0.65,0.8,1.0,1.45/                               FIG7  70
      DATA FA /1.17,0.741,0.661,0.952,1.15,1.15/                        FIG7  80
      DATA FB /-2.1,-2.39,-2.51,-1.66,-0.817,-0.376/                    FIG7  90
      I=0                                                               FIG7 100
      IF (X.LT.1.45) GO TO 100                                          FIG7 110
      Y=1                                                               FIG7 120
      RETURN                                                            FIG7 130
  100 I=I+1                                                             FIG7 140
      IF (X.GT.FX(I)) GO TO 100                                         FIG7 150
      Y=FA(I)*X**(FB(I))                                                FIG7 160
      RETURN                                                            FIG7 170
      END                                                               FIG7 180


      SUBROUTINE FIG8 (X,Y)                                             FIG8  10
C                                                                       FIG8  20
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIGURE 8 WHERE:            FIG8  30
C                   Y = F (KS / DELTA)                                  FIG8  40
C                                                                       FIG8  50
      DIMENSION FX(6),FA(6),FB(6)                                       FIG8  60
      DATA FX /0.66,0.84,1.1,1.3,2.2,3.1/                               FIG8  70
      DATA FA /0.997,0.911,0.814,0.858,0.957,0.714/                     FIG8  80
      DATA FB /1.18,0.966,0.323,-0.218,-0.635,-0.263/                   FIG8  90
      I=0                                                               FIG8 100
      IF (X.LT.3.1) GO TO 100                                           FIG8 110
      Y=.53                                                             FIG8 120
      RETURN                                                            FIG8 130
  100 I=I+1                                                             FIG8 140
      IF (X.GT.FX(I)) GO TO 100                                         FIG8 150
      Y=FA(I)*X**(FB(I))                                                FIG8 160
      RETURN                                                            FIG8 170
      END                                                               FIG8 180


      SUBROUTINE FIG10 (X,Y)                                            FG10  10
C                                                                       FG10  20
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIGURE 10 WHERE:           FG10  30
C                     PHI = F (PSI)                                     FG10  40
C                                                                       FG10  50
      DIMENSION FX(7),FA(7),FB(7)                                       FG10  60
      DATA FX /0.77,2.12,4.1,6.1,11.0,16.7,22.5/                        FG10  70
      DATA FA /7.56,5.35,4.1,4.1,4.6,5.66,9.28/                         FG10  80
      DATA FB /1.01,1.19,1.67,2.3,3.23,4.26,7.81/                       FG10  90
      I=0                                                               FG10 100
      IF (X.LT.22.5) GO TO 100                                          FG10 110
      Y=(13.1/X)**12.66                                                 FG10 120
```

```
      RETURN                                                          FG10 130
  100 I=I+1                                                           FG10 140
      IF (X.GT.FX(I)) GO TO 100                                       FG10 150
      Y=(FA(I)/X)**FB(I)                                              FG10 160
      RETURN                                                          FG10 170
      END                                                             FG10 180


      SUBROUTINE POWER (A,Z,FI1,FI2)                                  POWR  10
C                                                                     POWR  20
C     THIS SUBROUTINE EVALUATE I1 AND I2 INTEGRALS                    POWR  30
C                                                                     POWR  40
      N=1                                                             POWR  50
      FJ1=0.0                                                         POWR  60
      FJ2=0.0                                                         POWR  70
      FI1=0.0                                                         POWR  80
      FI2=0.0                                                         POWR  90
      COEFF=.216*A**(Z-1.0)/(1.0-A)**Z                                POWR 100
      ALG=ALOG(A)                                                     POWR 110
      C=1.0                                                           POWR 120
      D=-Z                                                            POWR 130
      E=D+1.0                                                         POWR 140
      FN=1.0                                                          POWR 150
      AEX=A**E                                                        POWR 160
      GO TO 120                                                       POWR 170
  110 N=N+1                                                           POWR 180
      C=C*D/FN                                                        POWR 190
      D=E                                                             POWR 200
      E=D+1.0                                                         POWR 210
      FN=FLOAT(N)                                                     POWR 220
      AEX=A**E                                                        POWR 230
  120 IF (ABS(E).LE.0.001) GO TO 130                                  POWR 240
      FJ1=FJ1+C*(1.0-AEX)/E                                           POWR 250
      FJ2=FJ2+C*((AEX-1.0)/E**2-AEX*ALG/E)                            POWR 260
      GO TO 140                                                       POWR 270
  130 FJ1=FJ1-C*ALG                                                   POWR 280
      FJ2=FJ2-0.5*C*ALG**2                                            POWR 290
  140 IF (N.EQ.1) GO TO 150                                           POWR 300
      CJ1=ABS(1.0-XJ1/FJ1)                                            POWR 310
      CJ2=ABS(1.0-XJ2/FJ2)                                            POWR 320
      IF (CJ1.LE.0.001.AND.CJ2.LE.0.001) GO TO 160                    POWR 330
  150 XJ1=FJ1                                                         POWR 340
      XJ2=FJ2                                                         POWR 350
      GO TO 110                                                       POWR 360
  160 FI1=COEFF*FJ1                                                   POWR 370
      FI2=COEFF*FJ2                                                   POWR 380
      RETURN                                                          POWR 390
      END                                                             POWR 400


      SUBROUTINE TOFF (NLD)                                           TOFF  10
```


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```
C                                                                       TOFF  20
C     TOFFALETI FORMULA                                                 TOFF  30
C                                                                       TOFF  40
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,  TOFF  50
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U, TOFF  60
     2 UGSI,V,W,XNU,Y                                                   TOFF  70
      DIMENSION DIP(18)                                                 TOFF  80
    1 FORMAT (1H ,'TOFFALETI',36X,'SIZE FRACTION DATA NOT GIVEN')       TOFF  90
    2 FORMAT (1H ,'TOFFALETI    D65 =',F6.2,' MM')                      TOFF 100
    3 FORMAT (1H ,'TOFFALETI    D65 =',F6.2,' MM',18X,F9.2,F13.4,F12.2) TOFF 110
    4 FORMAT (1H ,7X,'TOTAL',33X,F9.2,F13.4,F12.2)                      TOFF 120
      DATA DIP/0,.37,.71,.99,1.21,1.34,1.41,1.38,1.27,1.11,.94,.78,.65, TOFF 130
     1 .55,.49,.45,.42,.4/                                              TOFF 140
C                                                                       TOFF 150
      IF (SUMP.GT.0) GO TO 100                                          TOFF 160
      WRITE (6,1)                                                       TOFF 170
      RETURN                                                            TOFF 180
  100 IF (LSF.EQ.0) GO TO 110                                           TOFF 190
      WRITE (6,2) D65                                                   TOFF 200
      CALL PRFRAC(0)                                                    TOFF 210
  110 TDF=1.8*TEMP+32                                                   TOFF 220
      ZV=.1198+.00048*TDF                                               TOFF 230
      CZ=260.67-.667*TDF                                                TOFF 240
      YA=Y/11.24                                                        TOFF 250
      YB=Y/2.5                                                          TOFF 260
      CV=1.+ZV                                                          TOFF 270
      SI=S*Y*CZ                                                         TOFF 280
      U3=V**3/(XNU*G*S)                                                 TOFF 290
      U2=V/(DF65*G*S)**.5                                               TOFF 300
      F1=ALOG(U3)                                                       TOFF 310
      F2=4.083*ALOG(U2)-3.76                                            TOFF 320
      F3=1.864*F1-9.09                                                  TOFF 330
      IF (F3.GE.F2) GO TO 120                                           TOFF 340
      U1=F3                                                             TOFF 350
      GO TO 160                                                         TOFF 360
  120 FI=(F2+9.09)/1.864                                                TOFF 370
      FI=(F1-FI)*.43429                                                 TOFF 380
      IF (TI.LT.1.7) GO TO 130                                          TOFF 390
      U1=F2+.4                                                          TOFF 400
      GO TO 130                                                         TOFF 410
  130 F6=FI*10.                                                         TOFF 420
      DO 140 I=1,17                                                     TOFF 430
      F5=FLOAT(I)                                                       TOFF 440
      F1=F5-F6                                                          TOFF 450
      IF (F5.GE.F6) GO TO 150                                           TOFF 460
  140 CONTINUE                                                          TOFF 470
  150 J=F5                                                              TOFF 480
      F1=1.-F1                                                          TOFF 490
      F5=DIP(J)+F1*(DIP(J+1)-DIP(J))                                    TOFF 500
      U1=F2+F5                                                          TOFF 510
  160 AM=10.*V/U1                                                       TOFF 520
      PAM=(XNU*100000.)**.3333/AM                                       TOFF 530
      F1=100000.*PAM*S*DF65/G                                           TOFF 540
```

```
      T=(.051+.00009*TDF)*1.1                                          TOFF 550
      IF (PAM.GT.0.5) GO TO 170                                        TOFF 560
      A=9.8/(PAM**1.515)                                               TOFF 570
      GO TO 210                                                        TOFF 580
  170 IF (PAM.GT.0.66) GO TO 180                                       TOFF 590
      A=41.*PAM**.55                                                   TOFF 600
      GO TO 210                                                        TOFF 610
  180 IF (PAM.GT.0.72) GO TO 190                                       TOFF 620
      A=228.*PAM**4.68                                                 TOFF 630
      GO TO 210                                                        TOFF 640
  190 IF (PAM.GT.1.3) GO TO 200                                        TOFF 650
      A=49.                                                            TOFF 660
      GO TO 210                                                        TOFF 670
  200 A=23.5*PAM**2.8                                                  TOFF 680
  210 IF (F1.LE.0.25) GO TO 230                                        TOFF 690
      IF (F1.LE.0.35) GO TO 220                                        TOFF 700
      A=A*.5/F1**1.05                                                  TOFF 710
      GO TO 230                                                        TOFF 720
  220 A=A*5.2*F1**1.19                                                 TOFF 730
  230 IF (A.LT.16.) A=16.                                              TOFF 740
      CT=0                                                             TOFF 750
      UGS=0                                                            TOFF 760
      DO 300 I=2,9                                                     TOFF 770
      IF (I.GT.2) GO TO 240                                            TOFF 780
      GFB=1.905/(T*A/(V*V))**1.667                                     TOFF 790
      GO TO 250                                                        TOFF 800
  240 GFA=GFB                                                          TOFF 810
      GFB=GFA/3.175                                                    TOFF 820
  250 IF (PCT(I).LE.0.) GO TO 300                                      TOFF 830
      FV=1.6                                                           TOFF 840
      IF (I.LT.9) CALL FVEL (DFT(I),TEMP,FV)                           TOFF 850
      ZOM=FV*V/SI                                                      TOFF 860
      IF (ZOM.LT.(1.5*ZV)) ZOM=1.5*ZV                                  TOFF 870
      F1=.756*ZOM-ZV                                                   TOFF 880
      F2=ZOM-ZV                                                        TOFF 890
      F3=1.5*ZOM-ZV                                                    TOFF 900
      F4=1.-F1                                                         TOFF 910
      F5=1.-F2                                                         TOFF 920
      F6=1.-F3                                                         TOFF 930
      YAF4=YA**F4                                                      TOFF 940
      C=PCT(I)*W                                                       TOFF 950
      DD=2.*DFT(I)                                                     TOFF 960
      DDF4=DD**F4                                                      TOFF 970
      UD=CV*V*(DD/Y)**ZV                                               TOFF 980
      X=F4*GFB/(YAF4-DDF4)                                             TOFF 990
      UGSI=X*DDF4                                                      TOFF1000
      UBL=UGSI/(43.2*UD*DD)                                            TOFF1010
      IF (UBL.LE.100.) GO TO 260                                       TOFF1020
      UGSI=UGSI*100/UBL                                                TOFF1030
  260 UGSI=C*UGSI                                                      TOFF1040
      IF (NLD.EQ.2) GO TO 270                                          TOFF1050
      GA=UGSI+C*GFB                                                    TOFF1060
      C=C*X                                                            TOFF1070
```

```
      YAF2=YA**(F2-F1)                                          TOFF1080
      YAF5=YA**F5                                               TOFF1090
      CF5=C/F5                                                  TOFF1100
      YBF3=YB**(F3-F2)                                          TOFF1110
      YBF6=YB**F6                                               TOFF1120
      CF6=C/F6                                                  TOFF1130
      CF4=C/F4                                                  TOFF1140
      GB=CF5*YAF2*(YB**F5-YAF5)                                 TOFF1150
      GC=CF6*YAF2*YBF3*(Y**F6-YBF6)                             TOFF1160
      UGSI=GA+GB+GC                                             TOFF1170
  270 UGSI=UGSI/(43.2*W)                                        TOFF1180
      UGS=UGS+UGSI                                              TOFF1190
      CI=16000*UGSI/(Y*V)                                       TOFF1200
      CT=CT+CI                                                  TOFF1210
      IF (LSF.GT.0) CALL PRFRAC(I)                              TOFF1220
  300 CONTINUE                                                  TOFF1230
      GS=UGS*43.2*W                                             TOFF1240
      IF (LSF.GT.0) GO TO 310                                   TOFF1250
      WRITE (6,3) D65,CT,UGS,GS                                 TOFF1260
      RETURN                                                    TOFF1270
  310 WRITE (6,4) CT,UGS,GS                                     TOFF1280
      RETURN                                                    TOFF1290
      END                                                       TOFF1300
```

SUPPLEMENTAL DATA--SECTION C.

BASIC PROGRAM DISDATA LISTING

```
10 REM PROGRAM DISDATA
20 REM ENTER SEDIMENT DISCHARGE PROGRAM DATA TO INPUT FILE
30 REM MAXIMUM NUMBER OF DATA SETS IN A FILE IS 30.
40 REM STORES DATA ON SEQUENTIAL FILE DFILE$ AFTER EACH 10 ENTERED DATA SETS
50 DIM VAR(30,9),PCT(30,11),LO$(30),SIZELO(11),SIZEHI(11),PF(11)
60 LABEL$="  LOCWIDTHDEPTH VEL.SLOPETEMP.  D35  D50  D65  D90"
70 DATA .016,.062,.125,.25,.5,1,2,4,8,16,32
80 FOR I=1 TO 11 : READ SIZELO(I) : NEXT I
90 DATA .062,.125,.25,.5,1,2,4,8,16,32,64
100 FOR I=1 TO 11 : READ SIZEHI(I) : NEXT I
110 DFILE$="DISCH.DAT"
120 NN=25 : GOSUB 2520
130 PRINT "TURN ON PRINTER" : PRINT : PRINT "ESTABLISH FILE NAME:" : PRINT
140 PRINT "     1. USE PROGRAMMED FILE NAME (DISCH.DAT)"
150 PRINT "     2. PROVIDE FILE NAME"
160 NN=5 : GOSUB 2520
170 INPUT "ENTER NUMBER OF SELECTION --> ",I
180 IF I<2 THEN 210
190 NN=10 : GOSUB 2520
200 INPUT "DESIRED FILE NAME --> ",DFILE$
210 NN=10 : GOSUB 2520
220 PRINT "      1. ";DFILE$;" IS A NEW FILE"
230 PRINT "      2. ";DFILE$;" IS AN EXISTING FILE"
240 NN=3 : GOSUB 2520
250 INPUT "ENTER NUMBER OF SELECTION --> ",NFL
260 IF NFL>1 THEN 290
270 NO=0 : ND=0
280 GOTO 550
290 REM LOAD DATA FROM DISK * * * * * * * * * * * * * * * * * * * * * * * * * * *
300 NSZ=1
310 OPEN "I",#1,DFILE$
320 INPUT #1,NO
330 FOR N=1 TO NO
340 INPUT #1,LO$(N)
350 FOR I=1 TO 9 : INPUT #1,VAR(N,I) : NEXT I
360 FOR I=1 TO 11 : INPUT #1,PCT(N,I) : NEXT I
370 NEXT N
380 CLOSE
390 NN=25 : GOSUB 2520
400 PRINT "     0. END RUN USING FILE ";DFILE$
410 PRINT "     1. ADD DATA TO ";DFILE$
420 PRINT "     2. CORRECT DATA IN ";DFILE$
430 PRINT "     3. DISPLAY DATA IN ";DFILE$
440 PRINT "     4. PRINT DATA IN ";DFILE$
450 NN=5 : GOSUB 2520
460 INPUT "ENTER NUMBER OF SELECTION --> ",NC
470 IF NC>4 THEN 390
480 IF NC>0 THEN 530
490 NN=10 : GOSUB 2520
500 PRINT "FILE  ";DFILE$; : PRINT USING "  HAS ## DATA SETS";NO
510 PRINT : PRINT "END OF RUN"
```

```
520 END
530 ON NC GOTO 550,1230,1520,1670
540 REM ENTER DATA * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
550 NN=25 : GOSUB 2520
560 PRINT "METHOD OF ENTERING SIZE FRACTION DATA:"
570 PRINT
580 PRINT "     1. NO SIZE FRACTION DATA TO BE ENTERED"
590 PRINT "     2. DATA ENTERED BY PERCENT FINER VALUES"
600 PRINT "     3. DATA ENTERED BY PERCENT IN SIZE FRACTION"
610 NN=5 : GOSUB 2520
620 INPUT "ENTER NUMBER OF SELECTION --> ",NSZ
630 IF NSZ>3 THEN 550
640 IF NFL=1 OR NC=1 THEN 690
650 IF NO=30 THEN 1280
660 NN=25  : GOSUB 2520
670 PRINT : INPUT "ENTER MORE DATA  1 FOR YES  OR  2 FOR NO";I
680 IF I>1 THEN 1280
690 NO=NO+1 : ND=ND+1
700 IF ND<11 THEN 730
710 GOSUB 1120
720 ND=0
730 NN=25 : GOSUB 2520
740 PRINT "DATA SET NO. ";NO; : PRINT "    MAX = 30" : PRINT
750 PRINT : PRINT "ENTER LOCATION NAME  (MAX 80 CHARACTERS)"
760 LINE INPUT LO$(NO)
770 PRINT : INPUT "ENTER TOP WIDTH  (FT) --> ",VAR(NO,1)
780 PRINT : INPUT "ENTER AVERAGE DEPTH  (FT) --> ",VAR(NO,2)
790 PRINT : INPUT "ENTER AVERAGE VELOCITY (FT/SEC) --> ",VAR(NO,3)
800 PRINT : INPUT "ENTER WATER SURFACE SLOPE (FT/FT) --> ",VAR(NO,4)
810 PRINT : INPUT "ENTER WATER TEMPERATURE  (C) --> ",VAR(NO,5)
820 PRINT : INPUT "ENTER D35  (MM) OR 0 FOR NONE --> ",VAR(NO,6)
830 PRINT : INPUT "ENTER D50  (MM) --> ",VAR(NO,7)
840 PRINT : INPUT "ENTER D65  (MM) OR 0 FOR NONE --> ",VAR(NO,8)
850 PRINT : INPUT "ENTER D90  (MM) OR 0 FOR NONE --> ",VAR(NO,9)
860 NN=5 : GOSUB 2520
870 FOR I=1 TO 11 : PF(I)=0 : PCT(NO,I)=0 : NEXT I
880 ON NSZ GOTO 980,890,950
890 NPF=0
900 NPF=NPF+1
910 PRINT USING "ENTER PCT FINER THAN ##.### MM";SIZEHI(NPF); : INPUT " --> ";PF
(NPF)
920 IF PF(NPF)>99.9 THEN 980
930 IF NPF<11 THEN 900
940 GOTO 980
950 FOR I=1 TO 11
960 PRINT USING "ENTER % MATERIAL FOR ##.###";SIZELO(I); : PRINT USING "  TO  #
#.### MM  (0 FOR NONE)";SIZEHI(I); : INPUT " --> ",PCT((NO,I)
970 NEXT I
980 N=NO : GOSUB 2120
990 PRINT
1000 PRINT "     1 FOR DATA SET OK"
1010 PRINT "     2 TO RE-ENTER COMPLETE DATA SET"
1020 PRINT "     3 TO CORRECT PART OF DATA SET"
```

```
1030 PRINT : INPUT "ENTER NUMBER --> ",I
1040 IF I>3 THEN 980
1050 ON I GOTO 1060,730,1300
1060 IF NSZ<>2 THEN 650
1070 PCT(NO,1)=PF(1)
1080 FOR I=2 TO NPF
1090 PCT(NO,I)=PF(I)-PF(I-1)
1100 NEXT I
1110 GOTO 650
1120 REM STORE DATA ON DISK * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1130 OPEN "O",#1,DFILE$
1140 WRITE #1,NO
1150 FOR N=1 TO NO
1160 WRITE #1,LO$(N)
1170 FOR I=1 TO 9 : WRITE #1,VAR(N,I) : NEXT I
1180 FOR I=1 TO 11 : WRITE #1,PCT(N,I) : NEXT I
1190 NEXT N
1200 CLOSE
1210 RETURN
1220 END
1230 REM CORRECT DATA * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1240 NN=25 : GOSUB 2520
1250 PRINT USING "ENTER SET NUMBER  MAX = ##";NO; : PRINT "   0 TO END"; : INPUT
 " --> ",N
1260 IF N>NO THEN 1240
1270 IF N>0 THEN 1300
1280 GOSUB 1120
1290 GOTO 390
1300 GOSUB 2120
1310 PRINT : INPUT "ENTER VALUE NUMBER (1-21)  0 FOR NEW SET --> ",L
1320 IF L>21 THEN 1300
1330 IF L>0 THEN 1360
1340 IF NC=2 THEN 1240
1350 GOTO 980
1360 IF L>1 THEN 1410
1370 PRINT : PRINT "OLD LOCATION NAME IS " : PRINT LO$(N)
1380 PRINT "ENTER NEW LOCATION NAME  (MAX 80 CHARACTERS)"
1390 LINE INPUT LO$(N)
1400 GOTO 1300
1410 IF L>10 THEN 1450
1420 PRINT : PRINT "OLD ";MID$(LABEL$,(L-1)*5+1,5);" VALUE IS ";VAR(N,L-1)
1430 INPUT "ENTER NEW VALUE --> ",VAR(N,L-1)
1440 GOTO 1300
1450 I=L-10
1460 IF NSZ=2 THEN 1490
1470 PRINT : PRINT "OLD PERCENT VALUE IS ";PCT(N,I) : INPUT "ENTER NEW VALUE -->
 ",PCT(N,I)
1480 GOTO 1300
1490 PRINT : PRINT "OLD PCT FN VALUE IS ";PF(I) : INPUT "ENTER NEW VALUE --> ",P
F(I)
1500 IF PF(I)>99.9 OR I>NPF THEN NPF=I
1510 GOTO 1300
1520 REM LIST DATA ON SCREEN  * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

```
1530 NN=25 : GOSUB 2520
1540 PRINT "ENTER START SET NUMBER TO BE LISTED    0 TO END LISTING ";
1550 INPUT "--> ",NS1
1560 IF NS1=0 THEN 390
1570 IF NS1>NO THEN 1530
1580 NN=3 : GOSUB 2520
1590 PRINT USING "ENTER END SET NUMBER TO BE LISTED     MAX = ##";NO;
1600 INPUT "--> ",NS2
1610 IF NS2>NO THEN 1580
1620 FOR N=NS1 TO NS2
1630 GOSUB 2120
1640 PRINT : PRINT "PRESS ANY KEY TO CONTINUE"; : S$=INPUT$(1)
1650 NEXT N
1660 GOTO 1530
1670 REM LIST DATA ON PRINTER * * * * * * * * * * * * * * * * * * * * * * * * * *
1680 LPRINT "DATA STORED ON FILE ";DFILE$ : LPRINT
1690 NS=0
1700 NN=25 : GOSUB 2520
1710 PRINT "ENTER START SET NUMBER TO BE PRINTED   0 TO END PRINTING ";
1720 INPUT "--> ",NS1
1730 IF NS1=0 THEN 390
1740 IF NS1>NO THEN 1700
1750 NN=3 : GOSUB 2520
1760 PRINT USING "ENTER END SET NUMBER TO BE PRINTED    MAX = ## ";NO;
1770 INPUT "--> ",NS2
1780 IF NS2>NO THEN 1750
1790 FOR N=NS1 TO NS2
1800 NS=NS+1
1810 LPRINT "SET NUMBER  "N
1820 LPRINT " 1    LOC ";LO$(N)
1830 NR=1 : NL=1
1840 FOR I=1 TO 9 STEP 2
1850 NR=NR+1 : NL=NL+5
1860 LPRINT USING "##  ";NR; : LPRINT MID$(LABEL$,NL,5); : LPRINT USING "######.
###";VAR(N,I);
1870 IF I=9 THEN LPRINT : GOTO 1950
1880 NR=NR+1 : NL=NL+5
1890 LPRINT SPC(10); : LPRINT USING "##  ";NR; : LPRINT MID$(LABEL$,NL,5);
1900 IF I=3 THEN 1930
1910 LPRINT USING "######.###";VAR(N,I+1)
1920 GOTO 1940
1930 LPRINT USING "######.#######";VAR(N,I+1)
1940 NEXT I
1950 LPRINT "   PERCENT IN INDICATED SIZE FRACTION IN MM"
1960 FOR I=1 TO 11 STEP 2
1970 NR=NR+1
1980 LPRINT USING "##";NR; : LPRINT USING "#####.###";SIZELO(I),SIZEHI(I);
1990 LPRINT USING "####.##";PCT(N,I); : LPRINT SPC(6);
2000 IF I=11 THEN LPRINT : GOTO 2050
2010 NR=NR+1
2020 LPRINT USING "##";NR; : LPRINT USING "#####.###";SIZELO(I+1),SIZEHI(I+1);
2030 LPRINT USING "####.##";PCT(N,I+1)
2040 NEXT I
```

```
2050 IF NS=3 THEN 2080
2060 LPRINT : LPRINT : LPRINT
2070 GOTO 2100
2080 LPRINT CHR$(12);
2090 NS=0
2100 NEXT N
2110 GOTO 1700
2120 REM LIST ONE SET OF DATA ON SCREEN  * * * * * * * * * * * * * * * * * * * * *
2130 NN=25 : GOSUB 2520
2140 PRINT "SET NUMBER  "N
2150 PRINT " 1    LOC ";LO$(N)
2160 NR=1 : NL=1
2170 FOR I=1 TO 9 STEP 2
2180 NR=NR+1 : NL=NL+5
2190 PRINT USING "##  ";NR; : PRINT MID$(LABEL$,NL,5); : PRINT USING "######.###
";VAR(N,I);
2200 IF I=9 THEN PRINT : GOTO 2280
2210 NR=NR+1 : NL=NL+5
2220 PRINT SPC(10); : PRINT USING "##  ";NR; : PRINT MID$(LABEL$,NL,5);
2230 IF I=3 THEN 2260
2240 PRINT USING "######.###";VAR(N,I+1)
2250 GOTO 2270
2260 PRINT USING "######.#######";VAR(N,I+1)
2270 NEXT I
2280 IF NSZ=2 THEN 2400
2290 PRINT "   PERCENT IN INDICATED SIZE FRACTION IN MM"
2300 FOR I=1 TO 11 STEP 2
2310 NR=NR+1
2320 PRINT USING "##";NR; : PRINT USING "#####.###";SIZELO(I),SIZEHI(I);
2330 PRINT USING "####.##";PCT(N,I); : PRINT SPC(6);
2340 IF I=11 THEN PRINT : GOTO 2390
2350 NR=NR+1
2360 PRINT USING "##";NR; : PRINT USING "#####.###";SIZELO(I+1),SIZEHI(I+1);
2370 PRINT USING "####.##";PCT(N,I+1)
2380 NEXT I
2390 RETURN
2400 PRINT "   PERCENT FINER FOR INDICATED SIZE IN MM"
2410 FOR I=1 TO 11 STEP 2
2420 NR=NR+1
2430 PRINT USING "##";NR; : PRINT USING "#####.###";SIZEHI(I);
2440 PRINT USING "####.##";PF(I); : PRINT SPC(10);
2450 IF I=11 THEN PRINT : GOTO 2500
2460 NR=NR+1
2470 PRINT USING "##";NR; : PRINT USING "#####.###";SIZEHI(I+1);
2480 PRINT USING "####.##";PF(I+1)
2490 NEXT I
2500 RETURN
2510 END
2520 REM SUBROUTINE TO MOVE CURSOR DOWN NN LINES * * * * * * * * * * * * * * * *
2530 FOR LL=1 TO NN : PRINT : NEXT LL
2540 RETURN
2550 END
```

SUPPLEMENTAL DATA--SECTION D.

BASIC PROGRAM SEDDISCH LISTING

```
10 REM PROGRAM SEDDISCH
20 REM
30 REM COMPUTE BED-MATERIAL DISCHARGE & BEDLOAD DISCHARGE BY SELECTED FORMULAS
40 REM
50 DIM PCT(11),SIZELO(11),SIZEHI(11),DIA(11),DFT(11),NOSEL(2,12),AF(6,13),ZF(2),
NOS(2),TEMP(11),FG4(24),FG7(18),FG8(18),FG10(21),DIP(18),LABEL$(3),CY(7,7),CF(5)
60 DEF FNL(X)=LOG(X)/2.30259
70 GOSUB 1960
80 NOS(1)=0 : NOS(2)=0 : LSF=0
90 REM ENTER FORMULA NUMBERS TO BE COMPUTTED * * * * * * * * * * * * * * * * * * *
100 NN=25 : GOSUB 2600
110 PRINT "     1. BED-MATERIAL DISCHARGE FORMULAS"
120 PRINT "     2. BEDLOAD DISCHARGE FORMULAS"
130 PRINT "     3. BOTH TYPES OF FORMULAS"
140 NN=3 : GOSUB 2600
150 INPUT "ENTER NUMBER FOR TYPE(S) OF FORMULAS TO BE USED --> ",NTYPE
160 IF NTYPE>3 THEN 100
170 IF NTYPE=2 THEN 410
180 K=0 : N=1
190 NN=25 : GOSUB 2600
200 PRINT TAB(10);"BED-MATERIAL DISCHARGE FORMULA OPTIONS:" : PRINT
210 PRINT " 1. LAURSEN FORMULA   (USES SIZE FRACTIONS)"
220 PRINT " 2. ENGELUND AND HANSEN FORMULA  (USES D50)"
230 PRINT " 3. COLBY FORMULA  (USES D50)"
240 PRINT " 4. ACKERS AND WHITE FORMULA   (USING D50)"
250 PRINT " 5. ACKERS AND WHITE FORMULA   (USING D35)"
260 PRINT " 6. YANG SAND FORMULA   (USING D50)"
270 PRINT " 7. YANG SAND FORMULA   (USING SIZE FRACTIONS)"
280 PRINT " 8. YANG GRAVEL FORMULA   (USING D50)"
290 PRINT " 9. YANG GRAVEL FORMULA   (USING SIZE FRACTIONS)"
300 PRINT "10. COMBINE 7 AND 9  (USES SIZE FRACTIONS)"
310 PRINT "11. EINSTEIN FORMULA   (USES SIZE FRACTIONS)"
320 PRINT "12. TOFFALETI FORMULA   (USES SIZE FRACTIONS)"
330 NN=3 : GOSUB 2600
340 PRINT USING "ENTER FORMULA NUMBER FOR COMPUTATION NUMBER ##     (0 TO END)";
N; : INPUT " --> ",I
350 IF I>12 THEN 190
360 IF I=0 THEN 400
370 IF I=1 OR I=7 OR I>8 THEN LSF=LSF+1
380 K=K+1 : N=N+1 : NOSEL(1,K)=I
390 IF N<=12 THEN 190
400 NOS(1)=K
410 IF NTYPE=1 THEN 640
420 K=0 : N=1
430 NN=25 : GOSUB 2600
440 PRINT TAB(10);"BEDLOAD DISCHARGE FORMULA OPTIONS:" : PRINT
450 PRINT " 1. SCHOKLITSCH   (USES SIZE FRACTIONS)"
460 PRINT " 2. KALINSKE    (USES SIZE FRACTIONS)"
470 PRINT " 3. MEYER-PETER AND MULLER   (USES SIZE FRACTIONS)"
480 PRINT "    USE QS/Q=1 AND NS COMPUTED FROM EQUATION"
490 PRINT " 4. MEYER-PETER AND MULLER   (USES SIZE FRACTIONS)"
```

```
500 PRINT "    FOR RECTANGULAR CHANNEL AND ENTER ROUGHNESS VALUES"
510 PRINT " 5. MEYER-PETER AND MULLER   (USES SIZE FRACTIONS)"
520 PRINT "    FOR TRAPEZOIDAL CHANNEL AND ENTER ROUGHNESS VALUES"
530 PRINT " 6. ROTTNER FORMULA  (USES D50)"
540 PRINT " 7. EINSTEIN BEDLOAD FORMULA   (USES SIZE FRACTIONS)"
550 PRINT " 8. TOFFALETI FORMULA - BEDLOAD PART  (USES SIZE FRACTIONS)"
560 NN=3 : GOSUB 2600
570 PRINT USING "ENTER FORMULA NUMBER FOR COMPUTATION NUMBER ##     (0 TO END)";
N; : INPUT " --> ",I
580 IF I>8 THEN 430
590 IF I=0 THEN 630
600 IF I<3 OR I>6 THEN LSF=LSF+1
610 K=K+1 : N=N+1 : NOSEL(2,K)=I
620 IF N<=8 THEN 430
630 NOS(2)=K
640 IF LSF=0 THEN 740
650 NN=25 : GOSUB 2600
660 PRINT "LIST RESULTS OF FORMULAS THAT COMPUTE BY SIZE FRACTION" : PRINT
670 PRINT "     1. FOR EACH SIZE FRACTION AND TOTAL"
680 PRINT "     2. TOTAL ONLY"
690 NN=3 : GOSUB 2600
700 INPUT "ENTER LISTING SELECTION NUMBER --> ",I
710 IF I>2 THEN 650
720 IF I>1 THEN LSF=0
730 REM INPUT DATA * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
740 DFILE$="DISCH.DAT"
750 NN=25 : GOSUB 2600
760 PRINT "TURN ON PRINTER" : PRINT : PRINT "ESTABLISH FILE NAME:" : PRINT
770 PRINT "     1. USE PROGRAMMED FILE NAME (DISCH.DAT)"
780 PRINT "     2. PROVIDE FILE NAME"
790 NN=3 : GOSUB 2600
800 PRINT "ENTER NUMBER OF SELECTION "; : INPUT "--> ",I
810 IF I=1 THEN 840
820 NN=10 : GOSUB 2600
830 PRINT "ENTER DESIRED FILE NAME "; : INPUT "--> ",DFILE$
840 OPEN "I",#1,DFILE$
850 INPUT #1,NSAMP
860 FOR NS=1 TO NSAMP
870 SUMP=0
880 INPUT #1,L$
890 INPUT #1,W,Y,V,S,TEMP,D35,D50,D65,D90
900 INPUT #1,PCT(1),PCT(2),PCT(3),PCT(4),PCT(5),PCT(6),PCT(7),PCT(8),PCT(9),PCT(
10),PCT(11)
910 FOR I=1 TO 11 : SUMP=SUMP+PCT(I) : PCT(I)=PCT(I)/100! : NEXT I
920 COMP1=1.0334+.03672*TEMP+.0002058*TEMP*TEMP
930 XNU=.00002/COMP1
940 DF35=D35/304.8 : DF50=D50/304.8 : DF65=D65/304.8 : DF90=D90/304.8
950 COMP1=6*XNU
960 FV50=((36.064*DF50+COMP1).5-COMP1)/DF50
970 U=(G*Y*S).5
980 Q=W*Y*V
990 NN=25 : GOSUB 2600 : PRINT "DATA SET NUMBER ";NS : PRINT
1000 PRINT L$ : PRINT
```

```
1010 PRINT "TOP WIDTH";SPC(12); : PRINT USING "#####.## FEET";W;
1020 PRINT USING "      WATER SURF. SLOPE      ##.####### FT/FT";S
1030 PRINT "MEAN DEPTH";SPC(13); : PRINT USING "###.## FEET";Y;
1040 PRINT "      D50";SPC(18); : PRINT USING "##.### MILLIMETERS";D50
1050 PRINT "MEAN VELOCITY";SPC(9); : PRINT USING "##.## FT/SEC";V;
1060 PRINT USING "      KINEMATIC VISCOCITY          ##.#########";XNU
1070 PRINT "WATER DISCHARGE";SPC(5); : PRINT USING "#######.## CFS";Q;
1080 PRINT USING "      SED. FALL VELOCITY       ##.#### FT/SEC";FV50
1090 PRINT "WATER TEMPERATURE";SPC(7); : PRINT USING "##.# DEG C";TEMP
1100 NN=4 : GOSUB 2600
1110 LPRINT L$ : LPRINT
1120 LPRINT "TOP WIDTH";SPC(12); : LPRINT USING "#####.## FEET";W;
1130 LPRINT USING "      WATER SURF. SLOPE      ##.####### FT/FT";S
1140 LPRINT "MEAN DEPTH";SPC(13); : LPRINT USING "###.## FEET";Y;
1150 LPRINT "      D50";SPC(18); : LPRINT USING "##.### MILLIMETERS";D50
1160 LPRINT "MEAN VELOCITY";SPC(9); : LPRINT USING "##.## FT/SEC";V;
1170 LPRINT USING "      KINEMATIC VISCOCITY          ##.#########";XNU
1180 LPRINT "WATER DISCHARGE";SPC(5); : LPRINT USING "#######.## CFS";Q;
1190 LPRINT USING "      SED. FALL VELOCITY       ##.#### FT/SEC";FV50
1200 LPRINT "WATER TEMPERATURE";SPC(7); : LPRINT USING "##.# DEG C";TEMP
1210 IF NTYPE=2 THEN 1570
1220 LPRINT
1230 LPRINT TAB(10);"COMPUTED BED-MATERIAL CONCENTRATION AND DISCHARGE"
1240 LPRINT
1250 LPRINT "FORMULA";SPC(42);"CONC.   UNIT DISCH   DISCHARGE"
1260 LPRINT TAB(51);"PPM    LBS/SEC/FT   TONS/DAY"
1270 LPRINT
1280 FOR NO=1 TO NOS(1)
1290 IOS=NOSEL(1,NO)
1300 ON IOS GOTO 1310,1340,1370,1400,1400,1430,1460,1430,1460,1460,1490,1530
1310 REM LAURSEN FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * *
1320 GOSUB 2870
1330 GOTO 1560
1340 REM ENGELUND AND HANSEN FORMULA * * * * * * * * * * * * * * * * * * * * *
1350 GOSUB 3400
1360 GOTO 1560
1370 REM COLBY FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1380 GOSUB 3480
1390 GOTO 1560
1400 REM ACKERS AND WHITE FORMULA  * * * * * * * * * * * * * * * * * * * * * *
1410 GOSUB 3790
1420 GOTO 1560
1430 REM YANG SAND & GRAVEL FORMULAS USING D50 * * * * * * * * * * * * * * * *
1440 GOSUB 4190
1450 GOTO 1560
1460 REM YANG SAND & GRAVEL FORMULAS USING SIZE FRACTIONS  * * * * * * * * * *
1470 GOSUB 4480
1480 GOTO 1560
1490 REM EINSTEIN FORMULA  * * * * * * * * * * * * * * * * * * * * * * * * * *
1500 NLD=1
1510 GOSUB 6280
1520 GOTO 1560
1530 REM TOFFALETI FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * *
```

```
1540 NLD=1
1550 GOSUB 7550
1560 NEXT NO
1570 IF NTYPE=1 THEN 1870
1580 LPRINT
1590 LPRINT TAB(12);"COMPUTED BEDLOAD CONCENTRATION AND DISCHARGE"
1600 LPRINT
1610 LPRINT "FORMULA";SPC(42);"CONC.   UNIT DISCH   DISCHARGE"
1620 LPRINT TAB(51);"PPM    LBS/SEC/FT   TONS/DAY"
1630 LPRINT
1640 FOR NO=1 TO NOS(2)
1650 IOS=NOSEL(2,NO)
1660 ON IOS GOTO 1670,1700,1730,1730,1730,1760,1790,1830
1670 REM SCHOKLITCH FORMULA  * * * * * * * * * * * * * * * * * * * * * * * * * * *
1680 GOSUB 5090
1690 GOTO 1860
1700 REM KALINSKE FORMULA  * * * * * * * * * * * * * * * * * * * * * * * * * * *
1710 GOSUB 5380
1720 GOTO 1860
1730 REM MEYER-PETER AND MULLER FORMULA  * * * * * * * * * * * * * * * * * * * *
1740 GOSUB 5720
1750 GOTO 1860
1760 REM ROTTNER FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1770 GOSUB 6170
1780 GOTO 1860
1790 REM EINSTEIN BEDLOAD FORMULA  * * * * * * * * * * * * * * * * * * * * * * *
1800 NLD=2
1810 GOSUB 6280
1820 GOTO 1860
1830 REM TOFFALETI FORMULA  (BEDLOAD PORTION)  * * * * * * * * * * * * * * * * *
1840 NLD=2
1850 GOSUB 7550
1860 NEXT NO
1870 LPRINT : LPRINT
1880 LPRINT "* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 * * * * * *"
1890 LPRINT : LPRINT
1900 NEXT NS
1910 CLOSE 1
1920 NN=25 : GOSUB 2600
1930 PRINT "END OF RUN"
1940 NN=15 : GOSUB 2600
1950 END
1960 REM SUBROUTINE TO INPUT DATA STATEMENTS * * * * * * * * * * * * * * * * * *
1970 DATA 0.016,.062,.125,.25,.5,1,2,4,8,16,32
1980 FOR I=1 TO 11 : READ SIZELO(I) : NEXT I
1990 DATA 0.062,0.125,0.25,0.5,1,2,4,8,16,32,64
2000 FOR I=1 TO 11 : READ SIZEHI(I) : NEXT I
2010 FOR I=1 TO 11
2020 DIA(I)=(SIZELO(I)*SIZEHI(I)).5
2030 DFT(I)=DIA(I)/304.8
2040 NEXT I
2050 SG=2.65
```

```
2060 GMS=165.36
2070 G=32.1725
2080 DATA .00001,.001,.0001,.0001,.0001,.0001
2090 DATA .06,.24,.32,.4,.49,.57
2100 DATA .1,.6,.76,.92,1.1,1.26
2110 DATA .2,1.8,2.2,2.5,2.85,3.2
2120 DATA .4,4.6,5.3,5.8,6.3,6.7
2130 DATA .8,9.5,10.5,11,11.6,12
2140 DATA 1.5,16.1,16.9,17.5,17.9,18.1
2150 DATA 2,19.9,20.3,20.7,21.1,21.5
2160 DATA 3,25.3,25.6,25.9,26.2,26.5
2170 DATA 7,39.5,39.5,39.5,39.5,39.5
2180 DATA 8,41.5,41.5,41.5,41.5,41.5
2190 DATA 9,43.5,43.5,43.5,43.5,43.5
2200 DATA 10,45,45,45,45,45
2210 FOR I=1 TO 13
2220 READ AF(1,I),AF(2,I),AF(3,I),AF(4,I),AF(5,I),AF(6,I)
2230 NEXT I
2240 DATA -.068,-1.1328,.94,-1.206,.567,-.0975
2250 READ AK0,AK1,AK2,AK3,AK4,AK5
2260 DATA .5,1.9,1.72,.65,1.75,1.23,.9,1.62,.57,1.15,1.61,0,1.4,1.63,-.47,3.2,1.
72,-1.11,5,1.42,-.52,8.4,1.25,-.27
2270 FOR I=1 TO 24 : READ FG4(I) : NEXT I
2280 DATA .2,1.17,-2.1,.4,.741,-2.39,.65,.661,-2.51,.8,.952,-1.66,1,1.15,-.817,1
.45,1.15,-.376
2290 FOR I=1 TO 18 : READ FG7(I) : NEXT I
2300 DATA .66,.997,1.18,.84,.911,.966,1.1,.814,.323,1.3,.858,-.218,2.2,.957,-.63
5,3.1,.714,-.263
2310 FOR I=1 TO 18 : READ FG8(I) : NEXT I
2320 DATA .77,7.56,1.01,2.12,5.35,1.19,4.1,4.1,1.67,6.1,4.1,2.3,11,4.6,3.23,16.7
,5.66,4.26,22.5,9.28,7.81
2330 FOR I=1 TO 21 : READ FG10(I) : NEXT I
2340 DATA 0,.37,.71,.99,1.21,1.34,1.41,1.38,1.27,1.11,.94,.78,.65,.55,.49,.45,.4
2,.4
2350 FOR I=1 TO 18 : READ DIP(I) : NEXT I
2360 DATA .64,1,1,.88,.2
2370 FOR I=1 TO 5 : READ CF(I) : NEXT I
2380 DATA .1,.2,.3,.4,.8,0,0
2390 DATA .61,.48,.3,.3,.3,0,0
2400 DATA 1.453,1.329,1.4,1.26,1.099,0,0
2410 DATA .01,5,10,15.6,20,30,40
2420 DATA .1057,.0845,.0469,0,-.0277,-.0654,-.1155
2430 DATA .0735,.0166,.0014,0,-.0164,-.061,-.0763
2440 DATA .0118,.0202,.0135,0,0,0,0
2450 FOR I=1 TO 7
2460 READ CY(I,1),CY(I,2),CY(I,3),CY(I,4),CY(I,5),CY(I,6),CY(I,7)
2470 NEXT I
2480 RETURN
2490 END
2500 REM SUBROUTINE TO PRINT DISCHARGES BY SIZE FRACTION * * * * * * * * * * *
2510 IF NSF>0 THEN 2550
2520 LPRINT "          SIZE RANGE       FRACTION"
2530 LPRINT "       IN MILLIMETERS       IN BED"
```

```
2540 RETURN
2550 LPRINT TAB(6); : LPRINT USING "####.###";SIZELO(I),SIZEHI(I);
2560 LPRINT USING "######.###";PCT(I); : LPRINT SPC(13);
2570 LPRINT USING "#######.##";CI; : LPRINT USING "########.####";UGSI
2580 RETURN
2590 END
2600 REM SUBROUTINE TO MOVE CURSOR DOWN NN LINES * * * * * * * * * * * * * * * *
2610 FOR LL=1 TO NN : PRINT : NEXT LL
2620 RETURN
2630 END
2640 REM SUBROUTINE TO COMPUTE REPORT 12 SED FALL VEL, IN FT/SEC * * * * * * *
2650 REM INPUT DIAMETER IS IN FEET     TEMPERATURE IS IN DEG C * * * * * * * *
2660 REM MAX DIA IS 0.0328 FEET  (10 MM)   MAX TEMP IS 40 DEG C  * * * * * * *
2670 DFV=D*304.8
2680 SF=TEMP/10!
2690 KT=INT(SF)+1
2700 PT=SF-KT+1!
2710 DL=FNL(DFV)
2720 FOR M=1 TO 11
2730 IF DFV <= AF(1,M) THEN 2750
2740 NEXT M
2750 M=M-1
2760 CF=FNL(AF(1,M))
2770 EF=FNL(AF(1,M+1))
2780 PD=(DL-CF)/(EF-CF)
2790 FOR L=1 TO 2
2800 K=L+KT
2810 ZF(L)=(1!-PD)*FNL(AF(K,M))+PD*FNL(AF(K,M+1))
2820 NEXT L
2830 RF=(1!-PT)*ZF(1)+PT*ZF(2)
2840 FV=(10RF)/30.48
2850 RETURN
2860 END
2870 REM LAURSEN FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * * *
2880 IF SUMP>0 THEN 2910
2890 LPRINT "LAURSEN";SPC(38);"SIZE FRACTION DATA NOT GIVEN"
2900 RETURN
2910 IF LSF>0 THEN LPRINT "LAURSEN" : NSF=0 : GOSUB 2500
2920 C=0 : UGS=0
2930 DELTA=11.6*XNU/U
2940 FOR I=2 TO 11
2950 IF PCT(I)=0 THEN 3300
2960 COMP1=6*XNU
2970 FVI=((36.064*DFT(I)+COMP1).5-COMP1)/DFT(I)
2980 RV=U/FVI
2990 RVL=FNL(RV)
3000 IF RV>.3 THEN 3030
3010 FV=10.718*RV.243
3020 GOTO 3130
3030 IF RV>3 THEN 3060
3040 FV=10(.855*RVL+.62*RVL+1.2)
3050 GOTO 3130
3060 IF RV>20 THEN 3090
```

```
3070 FV=4.773*RV.304
3080 GOTO 3130
3090 IF RV>200 THEN 3120
3100 FV=10(3.764*RVL-.803*RVL+.147)
3110 GOTO 3130
3120 FV=9680.5*RV.2531
3130 RY=DFT(I)/DELTA
3140 IF RY>.03 THEN 3170
3150 YC=.16
3160 GOTO 3210
3170 IF RY>.1 THEN 3200
3180 YC=.08
3190 GOTO 3210
3200 YC=.04
3210 F1=(DFT(I)/Y)(7/6)
3220 F2=V*V/(58!*YC*DFT(I)*(SG-1)*G)
3230 F3=(DF50/Y)(1/3)
3240 CI=10000*PCT(I)*F1*(F2*F3-1)*FV
3250 IF CI<=0 THEN CI=0
3260 C=C+CI
3270 UGSI=.0000625*CI*Y*V
3280 UGS=UGS+UGSI
3290 IF LSF>0 THEN NSF=I : GOSUB 2500
3300 NEXT I
3310 GS=UGS*43.2*W
3320 IF LSF>0 THEN 3350
3330 LPRINT "LAURSEN";SPC(38);
3340 GOTO 3360
3350 LPRINT "       TOTAL";SPC(33);
3360 LPRINT USING "######.##";C; : LPRINT USING "########.####";UGS;
3370 LPRINT USING "#########.##";GS
3380 RETURN
3390 END
3400 REM ENGELUND AND HANSEN FORMULA * * * * * * * * * * * * * * * * * * * * * *
3410 UGS=.05*GMS*V*V*Y.5*S.5/(DF50*G.5*(SG-1))
3420 C=16000*UGS/(Y*V)
3430 GS=UGS*43.2*W
3440 LPRINT "ENGELUND & HANSEN";SPC(28); : LPRINT USING "######.##";C;
3450 LPRINT USING "########.####";UGS; : LPRINT USING "#########.##";GS
3460 RETURN
3470 END
3480 REM COLBY FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
3490 IF D50>=.1 AND D50<=.8 THEN 3520
3500 LPRINT "COLBY";SPC(40);"D50 LT 0.1 OR D50 GT 0.8"
3510 RETURN
3520 VC=.4673*Y.1*D50.333
3530 DIFF=V*.3048-VC
3540 B=2.5
3550 IF DIFF>=1 THEN B=1.453*D50(-.138)
3560 X=FNL(Y)
3570 N=0
3580 N=N+1
3590 IF TEMP>CY(4,N) THEN 3580
```

```
3600 F1=CY(5,N-1)+CY(6,N-1)*X+CY(7,N-1)*X*X
3610 F2=CY(5,N)+CY(6,N)*X+CY(7,N)*X*X
3620 AF=F1+(F2-F1)*(FNL(TEMP)-FNL(CY(4,N-1)))/(FNL(CY(4,N))-FNL(CY(4,N-1)))
3630 AF=10(AF)
3640 N=0
3650 N=N+1
3660 IF D50>CY(1,N) THEN 3650
3670 A=CY(3,N-1)*Y(CY(2,N-1))
3680 F1=A*DIFFB*(1+(AF-1)*CF(N-1))*.672
3690 A=CY(3,N)*Y(CY(2,N))
3700 F2=A*DIFFB*(1+(AF-1)*CF(N))*.672
3710 UGS=FNL(F1)+(FNL(F2)-FNL(F1))*(FNL(D50)-FNL(CY(1,N-1)))/(FNL(CY(1,N))-FNL(C
Y(1,N-1)))
3720 UGS=10GS
3730 C=16000*UGS/(Y*V)
3740 GS=UGS*43.2*W
3750 LPRINT "COLBY";SPC(40); : LPRINT USING "######.##";C;
3760 LPRINT USING "########.####";UGS; : LPRINT USING "#########.##";GS
3770 RETURN
3780 END
3790 REM ACKERS AND WHITE FORMULA  * * * * * * * * * * * * * * * * * * * * * * * *
3800 D=DF50
3810 IF IOS=4 THEN 3860
3820 IF DF35>0 THEN 3850
3830 LPRINT "ACKERS & WHITE  (USING D35)";SPC(18);"D35 NOT GIVEN"
3840 RETURN
3850 D=DF35
3860 DGR=D*((G*(SG-1)/(XNU*XNU)).3333)
3870 P=FNL(DGR)
3880 IF DGR>60 THEN 3950
3890 AN=1-.56*P
3900 AA=.23/SQR(DGR)+.14
3910 AM=9.66/DGR+1.34
3920 CA=2.86*P-P*P-3.53
3930 CA=10CA
3940 GOTO 3990
3950 AN=0
3960 AA=.17
3970 AM=1.5
3980 CA=.025
3990 F1=UAN/(SQR(G*D*(SG-1)))
4000 F2=(V/(SQR(G)*FNL(10!*Y/D)))(1-AN)
4010 F3=F1*F2/AA-1
4020 IF F3<0 THEN 4080
4030 GGR=CA*F3AM
4040 C=(GGR*D*SG*(V/U)AN)/Y
4050 C=C*10
4060 UGS=.0000625*C*Y*V
4070 GS=UGS*43.2*W
4080 IF IOS=5 THEN 4110
4090 LPRINT "ACKERS & WHITE  (USING D50)";SPC(18);
4100 GOTO 4120
```

```
4110 LPRINT "ACKERS & WHITE  (USING D35 = "; : LPRINT USING "#.### MM )";D35; :
LPRINT SPC(6);
4120 IF F3<0 THEN 4160
4130 LPRINT USING "######.##";C; : LPRINT USING "########.####";UGS;
4140 LPRINT USING "#########.##";GS
4150 RETURN
4160 LPRINT "COMPUTED CONCENTRATION LESS THAN ZERO"
4170 RETURN
4180 END
4190 REM YANG SAND & GRAVEL FORMULAS USING D50 * * * * * * * * * * * * * * * * * *
4200 REM USES REPORT 12 FALL VEL. WITH MAX DIA = 10 MM * * * * * * * * * * * * *
4210 FV=FV50
4220 IF DF50>=.0328 THEN 4250
4230 D=DF50
4240 GOSUB 2640
4250 R=U*DF50/XNU
4260 F1=2.05
4270 IF R>=70 THEN 4290
4280 F1=.66+2.5/(FNL(R)-.06)
4290 F2=FNL(FV*DF50/XNU)
4300 F3=FNL(U/FV)
4310 C=0
4320 F4=V*S/FV-F1*S
4330 IF IOS=8 THEN 4380
4340 IF F4<=0 THEN 4360
4350 C=5.435-.286*F2-.457*F3+(1.799-.409*F2-.314*F3)*FNL(F4)
4360 LPRINT "YANG SAND  (USING D50)";SPC(23);
4370 GOTO 4410
4380 IF F4<=0 THEN 4400
4390 C=6.681-.633*F2-4.816*F3+(2.784-.305*F2-.282*F3)*FNL(F4)
4400 LPRINT "YANG GRAVEL  (USING D50)";SPC(21);
4410 C=10C
4420 UGS=.0000625*C*Y*V
4430 GS=UGS*43.2*W
4440 LPRINT USING "######.##";C; : LPRINT USING "########.####";UGS;
4450 LPRINT USING "#########.##";GS
4460 RETURN
4470 END
4480 REM YANG SAND & GRAVEL FORMULAS USING SIZE FRACTIONS  * * * * * * * * * * *
4490 IF SUMP>0 THEN 4580
4500 ON (SGN(IOS-9)+2) GOTO 4510,4530,4550
4510 LPRINT "YANG SAND  (USING SIZE FRACTIONS)";SPC(12);
4520 GOTO 4560
4530 LPRINT "YANG GRAVEL  (USING SIZE FRACTIONS)";SPC(10);
4540 GOTO 4560
4550 LPRINT "YANG MIXTURE  (USING SIZE FRACTIONS)";SPC(9);
4560 LPRINT "SIZE FRACTION DATA NOT GIVEN"
4570 RETURN
4580 IF LSF=0 THEN 4660
4590 ON (SGN(IOS-9)+2) GOTO 4600,4620,4640
4600 LPRINT "YANG SAND  (USING SIZE FRACTIONS)"
4610 GOTO 4650
4620 LPRINT "YANG GRAVEL  (USING SIZE FRACTIONS)
```

```
4630 GOTO 4650
4640 LPRINT "YANG MIXTURE  (USING SIZE FRACTIONS)"
4650 NSF=0 : GOSUB 2500
4660 C=0 : UGS=0
4670 FOR I=2 TO 11
4680 IF PCT(I)=0 THEN 4940
4690 D=DFT(I)
4700 IF D<=.0328 THEN 4740
4710 COMP1=6*XNU
4720 FV=((36.064*D+COMP1).5-COMP1)/D
4730 GOTO 4750
4740 GOSUB 2640
4750 R=U*D/XNU
4760 F1=2.05
4770 IF R>=70 THEN 4790
4780 F1=.66+2.5/(FNL(R)-.06)
4790 F2=FNL(FV*D/XNU)
4800 F3=FNL(U/FV)
4810 CI=0
4820 F4=V*S/FV-F1*S
4830 IF F4<=0 THEN 4900
4840 IF IOS=9 THEN 4880
4850 IF IOS=10 AND I>6 THEN 4880
4860 CI=5.435-.286*F2-.457*F3+(1.799-.409*F2-.314*F3)*FNL(F4)
4870 GOTO 4890
4880 CI=6.681-.633*F2-4.816*F3+(2.784-.305*F2-.282*F3)*FNL(F4)
4890 CI=10CI*PCT(I)
4900 C=C+CI
4910 UGSI=.0000625*CI*Y*V
4920 UGS=UGS+UGSI
4930 IF LSF>0 THEN NSF=I : GOSUB 2500
4940 NEXT I
4950 GS=UGS*43.2*W
4960 IF LSF>0 THEN 5040
4970 ON (SGN(IOS-9)+2) GOTO 4980,5000,5020
4980 LPRINT "YANG SAND  (USING SIZE FRACTIONS)";SPC(12);
4990 GOTO 5050
5000 LPRINT "YANG GRAVEL  (USING SIZE FRACTIONS)";SPC(10);
5010 GOTO 5050
5020 LPRINT "YANG MIXTURE  (USING SIZE FRACTIONS)";SPC(9);
5030 GOTO 5050
5040 LPRINT "       TOTAL";SPC(33);
5050 LPRINT USING "######.##";C; : LPRINT USING "########.####";UGS;
5060 LPRINT USING "#########.##";GS
5070 RETURN
5080 END
5090 REM SCHOKLITSCH FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
5100 IF SUMP>0 THEN 5130
5110 LPRINT "SCHOKLITSCH";SPC(34);"SIZE FRACTION DATA NOT GIVEN"
5120 RETURN
5130 IF LSF>0 THEN LPRINT "SCHOKLITSCH" : NSF=0 : GOSUB 2500
5140 F1=25*S.5*V*Y
5150 F2=1.6*S.17
```

```
5160 C=0 : UGS=0
5170 FOR I=1 TO 11
5180 IF PCT(I)=0 THEN 5280
5190 CI=0 : UGSI=0
5200 F3=DFT(I).5
5210 X=F1/F3-F2*F3
5220 IF X<0 THEN 5240
5230 UGSI=X*PCT(I)
5240 UGS=UGS+UGSI
5250 CI=16000*UGSI/(Y*V)
5260 C=C+CI
5270 IF LSF>0 THEN NSF=I : GOSUB 2500
5280 NEXT I
5290 GS=UGS*43.2*W
5300 IF LSF>0 THEN 5330
5310 LPRINT "SCHOKLITSCH";SPC(34);
5320 GOTO 5340
5330 LPRINT "       TOTAL";SPC(33);
5340 LPRINT USING "######.##";C; : LPRINT USING "########.####";UGS;
5350 LPRINT USING "##########.##";GS
5360 RETURN
5370 END
5380 REM KALINSKE FORMULA  * * * * * * * * * * * * * * * * * * * * * * * * * * * *
5390 IF SUMP>0 THEN 5420
5400 LPRINT "KALINSKE";SPC(37);"SIZE FRACTION DATA NOT GIVEN"
5410 RETURN
5420 IF LSF>0 THEN LPRINT "KALINSKE" : NSF=0 : GOSUB 2500
5430 S1=0
5440 FOR I=1 TO 11
5450 TEMP(I)=PCT(I)/DFT(I)
5460 S1=S1+TEMP(I)
5470 NEXT I
5480 T0=62.4*Y*S
5490 F1=25.28*T0.5/S1
5500 C=0 : UGS=0
5510 FOR I=1 TO 11
5520 IF PCT(I)=0 THEN 5620
5530 T1=12*DFT(I)
5540 X=T1/T0
5550 F2=AK0+AK1*X+AK2*X+AK3*X+AK4*X+AK5*X
5560 F2=10(F2)
5570 UGSI=F1*T1*TEMP(I)*F2
5580 UGS=UGS+UGSI
5590 CI=16000*UGSI/(Y*V)
5600 C=C+CI
5610 IF LSF>0 THEN NSF=I : GOSUB 2500
5620 NEXT I
5630 GS=UGS*43.2*W
5640 IF LSF>0 THEN 5670
5650 LPRINT "KALINSKE";SPC(37);
5660 GOTO 5680
5670 LPRINT "       TOTAL";SPC(33);
5680 LPRINT USING "######.##";C; : LPRINT USING "########.####";UGS;
```

```
5690 LPRINT USING "#########.##";GS
5700 RETURN
5710 END
5720 REM MEYER-PETER AND MULLER FORMULA  * * * * * * * * * * * * * * * * * * * * * *
5730 LABEL$(1)="QS/Q=1 AND NS=STRICKLER ROUGHNESS"
5740 LABEL$(2)="RECTANGULAR CHANNEL AND COMPUTE NS AND QS/Q"
5750 LABEL$(3)="TRAPEZOIDAL CHANNEL AND COMPUTE NS AND QS/Q"
5760 IF SUMP>0 THEN 5790
5770 LPRINT "MEYER-PETER & MULLER";SPC(25);"SIZE FRACTION DATA NOT GIVEN"
5780 RETURN
5790 DM=0
5800 FOR I=1 TO 11
5810 DM=DM+PCT(I)*DIA(I)
5820 NEXT I
5830 UGS=0
5840 IF IOS>3 THEN 5880
5850 QSQ=1
5860 RNS=1.486*Y.667*S.5/V
5870 GOTO 6010
5880 PRINT "MEYER-PETER AND MULLER   ";LABEL$(IOS-2)
5890 INPUT "ENTER MANNING'S N FOR CHANNEL SIDES (NW) --> ",RNW
5900 INPUT "ENTER MANNING'S N FOR TOTAL STREAM  (NM) --> ",RNM
5910 IF IOS=5 THEN 5950
5920 PRINT
5930 F1=2*Y/W
5940 GOTO 5990
5950 INPUT "ENTER BOTTOM WIDTH, IN FEET --> ",BW
5960 PRINT
5970 F2=(W-BW)/2/Y
5980 F1=2*Y*(1+F2).5/BW
5990 RNS=RNM*(1+F1*(1-(RNW/RNM).5)).667
6000 QSQ=1/(1+F1*(RNW/RNS).5)
6010 UGS=0
6020 F1=.368*QSQ*(D90.1667/RNS).5*Y*S-.0698*DM
6030 IF F1>0 THEN UGS=F1.5
6040 C=16000*UGS/(Y*V)
6050 GS=UGS*43.2*W
6060 IF IOS=5 THEN 6090
6070 LPRINT "MEYER-PETER & MULLER"
6080 GOTO 6100
6090 LPRINT "MEYER-PETER & MULLER      BOT WIDTH = "; : LPRINT USING "####.##";B
W
6100 LPRINT "  ";LABEL$(IOS-2)
6110 LPRINT USING "  D90 = ##.### MM";D90; : LPRINT USING "    M-P DM = ##.### M
M";DM
6120 IF IOS>3 THEN LPRINT USING "  NW = ##.###";RNW; : LPRINT USING "    NM = ##
.###";RNM
6130 LPRINT USING "  QS/Q = ##.###";QSQ; : LPRINT USING "    NS = ##.####";RNS;
: LPRINT SPC(14); : LPRINT USING "#######.##";C;
6140 LPRINT USING "########.####";UGS; : LPRINT USING "#########.##";GS
6150 RETURN
6160 END
6170 REM ROTTNER FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

```
6180 R=(DF50/Y).667
6190 F1=V/(7.286*Y.5)
6200 F2=.667*R+.14
6210 UGS=1204.8*Y.5*(F1*F2-.778*R)
6220 C=16000*UGS/(Y*V)
6230 GS=UGS*43.2*W
6240 LPRINT "ROTTNER";SPC(38); : LPRINT USING "######.##";C;
6250 LPRINT USING "########.####";UGS; : LPRINT USING "#########.##";GS
6260 RETURN
6270 END
6280 REM EINSTEIN FORMULA  * * * * * * * * * * * * * * * * * * * * * * * * * * * *
6290 IF SUMP>0 THEN 6320
6300 LPRINT "EINSTEIN";SPC(37);"SIZE FRACTION DATA NOT GIVEN"
6310 RETURN
6320 LPRINT "EINSTEIN"
6330 IF LSF>0 THEN LPRINT USING "  D35 = ##.### MM";D35; : LPRINT USING "    D65
 = ##.### MM";D65 : NSF=0 : GOSUB 2500
6340 RB=Y : CT=0 : UGS=0
6350 RBP=(V*DF65.1667/(7.66*(G*S).5)).5
6360 RBPP=RB-RBP
6370 SVP=(G*RBP*S).5
6380 DELTA=11.6*XNU/SVP
6390 X9=DF65/DELTA
6400 GOSUB 6800
6410 DELT=DF65/XR
6420 COMP1=DELT/DELTA
6430 IF COMP1<1.8 THEN 6460
6440 CAPX=.77*DELT
6450 GOTO 6470
6460 CAPX=1.39*DELTA
6470 GOSUB 7020
6480 BETAX=FNL(10.6*CAPX/DELT)
6490 PVALUE=2.3026*FNL(30.2*XR*RB/DF65)
6500 COMP1=6*XNU
6510 FOR I=1 TO 11
6520 IF PCT(I)=0 THEN 6710
6530 X9=DFT(I)/CAPX
6540 GOSUB 6920
6550 PSIS=XI*CAPY*(1.025/BETAX)*(1.65*DFT(I)/(RBP*S))
6560 X9=PSIS
6570 GOSUB 7120
6580 UNITBD=1200*PHI*DFT(I).5*PCT(I)
6590 UGSI=UNITBD
6600 IF NLD=2 THEN 6670
6610 FVI=((36.064*DFT(I)+COMP1).5-COMP1)/DFT(I)
6620 Z=FVI/(.4*SVP)
6630 A=2*DFT(I)/RB
6640 FI1=0 : FI2=0
6650 GOSUB 7220
6660 UGSI=UNITBD*(PVALUE*FI1+FI2+1)
6670 UGS=UGS+UGSI
6680 CI=16000*UGSI/(Y*V)
6690 CT=CT+CI
```

```
6700 IF LSF>0 THEN NSF=I : GOSUB 2500
6710 NEXT I
6720 GS=UGS*43.2*W
6730 IF LSF>0 THEN 6760
6740 LPRINT USING "  D35 = ##.### MM";D35; : LPRINT USING "    D65 = ##.### MM";
D65; : LPRINT SPC(9); : LPRINT USING "######.##";CT;
6750 GOTO 6770
6760 LPRINT "       TOTAL";SPC(33); : LPRINT USING "######.##";CT;
6770 LPRINT USING "########.####";UGS; : LPRINT USING "#########.##";GS
6780 RETURN
6790 END
6800 REM SUBROUTINE FIG 4  * * * * * * * * * * * * * * * * * * * * * * * * * * * *
6810 J9=-2
6820 XR=.4
6830 IF X9<.135 THEN 6860
6840 IF X9<8.4 THEN 6870
6850 XR=1
6860 RETURN
6870 J9=J9+3
6880 IF X9>FG4(J9) THEN 6870
6890 XR=FG4(J9+2)*FNL(X9)+FG4(J9+1)
6900 RETURN
6910 END
6920 REM SUBROUTINE FIG 7  * * * * * * * * * * * * * * * * * * * * * * * * * * * *
6930 J9=-2
6940 IF X9<1.45 THEN 6970
6950 XI=1
6960 RETURN
6970 J9=J9+3
6980 IF X9>FG7(J9) THEN 6970
6990 XI=FG7(J9+1)*X9(FG7(J9+2))
7000 RETURN
7010 END
7020 REM SUBROUTINE FIG 8  * * * * * * * * * * * * * * * * * * * * * * * * * * * *
7030 J9=-2
7040 IF X9<3.1 THEN 7070
7050 CAPY=.53
7060 RETURN
7070 J9=J9+3
7080 IF X9>FG8(J9) THEN 7070
7090 CAPY=FG8(J9+1)*X9(FG8(J9+2))
7100 RETURN
7110 END
7120 REM SUBROUTINE FIG 10 * * * * * * * * * * * * * * * * * * * * * * * * * * * *
7130 J9=-2
7140 IF X9<22.5 THEN 7170
7150 PHI=(13.1/X9).66
7160 RETURN
7170 J9=J9+3
7180 IF X9>FG10(J9) THEN 7170
7190 PHI=(FG10(J9+1)/X9)FG10(J9+2)
7200 RETURN
7210 END
```

```
7220 REM SUBROUTINE POWER  * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
7230 N=1 : FJ1=0 : FJ2=0 : FI1=0 : FI2=0
7240 FACT=.216*A(Z-1)/(1-A)Z
7250 ALG=LOG(A)
7260 C=1
7270 D=-Z
7280 E=D+1
7290 NN=1
7300 AEX=A
7310 GOTO 7380
7320 N=N+1
7330 C=C*D/NN
7340 D=E
7350 E=D+1
7360 NN=N
7370 AEX=A
7380 IF ABS(E)<=.001 THEN 7420
7390 FJ1=FJ1+C*(1-AEX)/E
7400 FJ2=FJ2+C*((AEX-1)/E-AEX*ALG/E)
7410 GOTO 7440
7420 FJ1=FJ1-C*ALG
7430 FJ2=FJ2-.5*C*ALG
7440 IF N=1 THEN 7480
7450 CJ1=ABS(1-XJ1/FJ1)
7460 CJ2=ABS(1-XJ2/FJ2)
7470 IF CJ1<=.001 AND CJ2<=.001 THEN 7510
7480 XJ1=FJ1
7490 XJ2=FJ2
7500 GOTO 7320
7510 FI1=FACT*FJ1
7520 FI2=FACT*FJ2
7530 RETURN
7540 END
7550 REM TOFFALETI FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
7560 IF SUMP>0 THEN 7590
7570 LPRINT "TOFFALETI";SPC(36);"SIZE FRACTION DATA NOT GIVEN"
7580 RETURN
7590 IF LSF=0 THEN 7620
7600 LPRINT USING "TOFFALETI    D65 = ##.### MM";D65
7610 NSF=0 : GOSUB 2500
7620 TDF=1.8*TEMP+32
7630 ZV=.1198+.00048*TDF
7640 CZ=260.67-.667*TDF
7650 YA=Y/11.24
7660 YB=Y/2.5
7670 CV=1!+ZV
7680 SI=S*Y*CZ
7690 U3=V/(XNU*G*S)
7700 U2=V/(DF65*G*S).5
7710 F1=LOG(U3)
7720 F2=4.083*LOG(U2)-3.76
7730 F3=1.864*F1-9.09
7740 IF F3>F2 THEN 7770
```

```
7750 U1=F3
7760 GOTO 7910
7770 FI=(F2+9.09)/1.864
7780 FI=(F1-FI)*.43429
7790 IF TI<1.7 THEN 7820
7800 U1=F2+.4
7810 GOTO 7910
7820 F6=FI*10!
7830 FOR F5=1! TO 17!
7840 F1=F5-F6
7850 IF F5>=F6 THEN 7870
7860 NEXT F5
7870 J=F5
7880 F1=1!-F1
7890 F5=DIP(J)+F1*(DIP(J+1)-DIP(J))
7900 U1=F2+F5
7910 AM=10!*V/U1
7920 PAM=(XNU*100000!).3333/AM
7930 F1=100000!*PAM*S*DF65/G
7940 T=(.051+.00009*TDF)*1.1
7950 IF PAM>.5 THEN 7980
7960 A=9.8/(PAM.515)
7970 GOTO 8080
7980 IF PAM>.66 THEN 8010
7990 A=41!*PAM.55
8000 GOTO 8080
8010 IF PAM>.72 THEN 8040
8020 A=228!*PAM.68
8030 GOTO 8080
8040 IF PAM>1.3 THEN 8070
8050 A=49!
8060 GOTO 8080
8070 A=23.5*PAM.8
8080 IF F1<=.25 THEN 8130
8090 IF F1<=.35 THEN 8120
8100 A=A*.5/F1.05
8110 GOTO 8130
8120 A=A*5.2*F1.19
8130 IF A<16! THEN A=16!
8140 CT=0 : UGS=0
8150 FOR I=2 TO 9
8160 IF I>2 THEN 8190
8170 GFB=1.905/(T*A/(V*V)).667
8180 GOTO 8210
8190 GFA=GFB
8200 GFB=GFA/3.175
8210 IF PCT(I)=0 THEN 8620
8220 IF I=9 THEN FV=1.6 : GOTO 8250
8230 D=DFT(I)
8240 GOSUB 2640
8250 ZOM=FV*V/SI
8260 IF ZOM<(1.5*ZV) THEN ZOM=1.5*ZV
8270 F1=.756*ZOM-ZV
```

```
8280 F2=ZOM-ZV
8290 F3=1.5*ZOM-ZV
8300 F4=1!-F1
8310 F5=1!-F2
8320 F6=1!-F3
8330 YAF4=YAF4
8340 C=PCT(I)*W
8350 DD=2!*DFT(I)
8360 DDF4=DDF4
8370 UD=CV*V*(DD/Y)ZV
8380 X=F4*GFB/(YAF4-DDF4)
8390 UGSI=X*DDF4
8400 UBL=UGSI/(43.2*UD*DD)
8410 IF UBL<=100 THEN 8430
8420 UGSI=UGSI*100/UBL
8430 UGSI=C*UGSI
8440 IF NLD=2 THEN 8570
8450 GA=UGSI+C*GFB
8460 C=C*X
8470 YAF2=YA(F2-F1)
8480 YAF5=YAF5
8490 CF5=C/F5
8500 YBF3=YB(F3-F2)
8510 YBF6=YBF6
8520 CF6=C/F6
8530 CF4=C/F4
8540 GB=CF5*YAF2*(YBF5-YAF5)
8550 GC=CF6*YAF2*YBF3*(YF6-YBF6)
8560 UGSI=GA+GB+GC
8570 UGSI=UGSI/(43.2*W)
8580 UGS=UGS+UGSI
8590 CI=16000*UGSI/(Y*V)
8600 CT=CT+CI
8610 IF LSF>0 THEN NSF=I : GOSUB 2500
8620 NEXT I
8630 GS=UGS*43.2*W
8640 IF LSF>0 THEN 8670
8650 LPRINT USING "TOFFALETI    D65 = ##.### MM";D65; : LPRINT SPC(17);
8660 GOTO 8680
8670 LPRINT "       TOTAL";SPC(33);
8680 LPRINT USING "######.##";CT; : LPRINT USING "########.####";UGS;
8690 LPRINT USING "##########.##";GS
8700 RETURN
8710 END
```

SUPPLEMENTAL DATA—SECTION E.

EXAMPLES OF PROGRAM DISDATA OUTPUT

DATA STORED ON FILE REPT1.DAT

SET NUMBER 1

1	LOC	RIO GRANDE RIVER NR BERNALILLO, NM					SECT	A2								
2	WIDTH	272.000		3	DEPTH	2.470		4	VEL.	4.060		5	SLOPE	0.0008900		
6	TEMP.	14.400		7	D35	0.191		8	D50	0.231		9	D65	0.280	10	D90	0.445
	PERCENT IN INDICATED SIZE FRACTION, IN MM															
11	0.016	0.062	2.10	12	0.062	0.125	8.70	13	0.125	0.250	45.70					
14	0.250	0.500	36.90	15	0.500	1.000	4.80	16	1.000	2.000	0.60					
17	2.000	4.000	0.40	18	4.000	8.000	0.30	19	8.000	16.000	0.50					
20	16.000	32.000	0.00	21	32.000	64.000	0.00									

DATA STORED ON FILE REPT2.DAT

SET NUMBER 1

1	LOC	NIOBRARA RIVER NR CODY, NE														
2	WIDTH	70.000		3	DEPTH	1.560		4	VEL.	2.150		5	SLOPE	0.0012500		
6	TEMP.	20.000		7	D35	0.000		8	D50	0.276		9	D65	0.000	10	D90	0.000
	PERCENT IN INDICATED SIZE FRACTION, IN MM															
11	0.016	0.062	0.00	12	0.062	0.125	0.00	13	0.125	0.250	0.00					
14	0.250	0.500	0.00	15	0.500	1.000	0.00	16	1.000	2.000	0.00					
17	2.000	4.000	0.00	18	4.000	8.000	0.00	19	8.000	16.000	0.00					
20	16.000	32.000	0.00	21	32.000	64.000	0.00									

SUPPLEMENTAL DATA--SECTION F.

EXAMPLES OF PROGRAM SEDDISCH OUTPUT

Run number 1. Output from data file REPT1.DAT with size fraction listing.

RIO GRANDE RIVER NR BERNALILLO, NM SECT A2

TOP WIDTH	272.00 FEET	WATER SURF. SLOPE	0.0008900 FT/FT
MEAN DEPTH	2.47 FEET	D50	0.231 MILLIMETERS
MEAN VELOCITY	4.06 FT/SEC	KINEMATIC VISCOCITY	0.00001246
WATER DISCHARGE	2727.67 CFS	SED. FALL VELOCITY	0.0939 FT/SEC
WATER TEMPERATURE	14.4 DEG C		

COMPUTED BED-MATERIAL CONCENTRATION AND DISCHARGE

FORMULA	SIZE RANGE IN MILLIMETERS		FRACTION IN BED	CONC. PPM	UNIT DISCH LBS/SEC/FT	DISCHARGE TONS/DAY
LAURSEN						
	0.062	0.125	0.087	1354.55	0.8490	
	0.125	0.250	0.457	479.02	0.3002	
	0.250	0.500	0.369	92.58	0.0580	
	0.500	1.000	0.048	6.62	0.0041	
	1.000	2.000	0.006	0.44	0.0003	
	2.000	4.000	0.004	0.00	0.0000	
	4.000	8.000	0.003	0.00	0.0000	
	8.000	16.000	0.005	0.00	0.0000	
	TOTAL			1933.22	1.2117	14237.57
ENGELUND & HANSEN				1919.65	1.2032	14137.65
ACKERS & WHITE (USING D50)				2210.88	1.3857	16282.46
YANG SAND (USING D50)				1200.47	0.7524	8841.12
YANG SAND (USING SIZE FRACTIONS)						
	SIZE RANGE IN MILLIMETERS		FRACTION IN BED			
	0.062	0.125	0.087	514.54	0.3225	
	0.125	0.250	0.457	774.49	0.4854	
	0.250	0.500	0.369	291.73	0.1828	
	0.500	1.000	0.048	26.70	0.0167	
	1.000	2.000	0.006	3.09	0.0019	
	2.000	4.000	0.004	2.30	0.0014	
	4.000	8.000	0.003	2.11	0.0013	
	8.000	16.000	0.005	6.60	0.0041	
	TOTAL			1621.56	1.0163	11942.29
EINSTEIN						
D35 = 0.191 MM	D65 = 0.280 MM					
	SIZE RANGE IN MILLIMETERS		FRACTION IN BED			
	0.016	0.062	0.021	2.60	0.0016	
	0.062	0.125	0.087	324.68	0.2035	
	0.125	0.250	0.457	443.75	0.2781	
	0.250	0.500	0.369	303.97	0.1905	
	0.500	1.000	0.048	44.17	0.0277	

1.000	2.000	0.006	4.28	0.0027	
2.000	4.000	0.004	1.13	0.0007	
4.000	8.000	0.003	0.15	0.0001	
8.000	16.000	0.005	0.00	0.0000	
TOTAL			1124.72	0.7049	8283.25

COMPUTED BEDLOAD CONCENTRATION AND DISCHARGE

FORMULA			CONC. PPM	UNIT DISCH LBS/SEC/FT	DISCHARGE TONS/DAY
SCHOKLITSCH					
SIZE RANGE IN MILLIMETERS		FRACTION IN BED			
0.016	0.062	0.021	21.78	0.0136	
0.062	0.125	0.087	53.22	0.0334	
0.125	0.250	0.457	193.03	0.1210	
0.250	0.500	0.369	105.35	0.0660	
0.500	1.000	0.048	8.80	0.0055	
1.000	2.000	0.006	0.62	0.0004	
2.000	4.000	0.004	0.14	0.0001	
4.000	8.000	0.003	0.00	0.0000	
8.000	16.000	0.005	0.00	0.0000	
TOTAL			382.93	0.2400	2820.18
KALINSKE					
SIZE RANGE IN MILLIMETERS		FRACTION IN BED			
0.016	0.062	0.021	1.93	0.0012	
0.062	0.125	0.087	7.65	0.0048	
0.125	0.250	0.457	37.77	0.0237	
0.250	0.500	0.369	27.10	0.0170	
0.500	1.000	0.048	2.84	0.0018	
1.000	2.000	0.006	0.24	0.0002	
2.000	4.000	0.004	0.07	0.0000	
4.000	8.000	0.003	0.01	0.0000	
8.000	16.000	0.005	0.00	0.0000	
TOTAL			77.61	0.0486	571.55

* * * *

Run number 2. Output from data file REPT1.DAT with only totals listed.

RIO GRANDE RIVER NR BERNALILLO, NM SECT A2

TOP WIDTH	272.00 FEET	WATER SURF. SLOPE	0.0008900 FT/FT
MEAN DEPTH	2.47 FEET	D50	0.231 MILLIMETERS
MEAN VELOCITY	4.06 FT/SEC	KINEMATIC VISCOCITY	0.00001246
WATER DISCHARGE	2727.67 CFS	SED. FALL VELOCITY	0.0939 FT/SEC
WATER TEMPERATURE	14.4 DEG C		

COMPUTED BED-MATERIAL CONCENTRATION AND DISCHARGE

FORMULA	CONC. PPM	UNIT DISCH LBS/SEC/FT	DISCHARGE TONS/DAY
LAURSEN	1933.22	1.2117	14237.57
ENGELUND & HANSEN	1919.65	1.2032	14137.65
COLBY	1768.79	1.1086	13026.59
ACKERS & WHITE (USING D50)	2210.88	1.3857	16282.46
YANG SAND (USING D50)	1200.47	0.7524	8841.12
YANG SAND (USING SIZE FRACTIONS)	1621.56	1.0163	11942.29
EINSTEIN D35 = 0.191 MM D65 = 0.280 MM	1124.72	0.7049	8283.25
TOFFALETI D65 = 0.28 MM	3791.49	2.3764	27923.23

COMPUTED BEDLOAD CONCENTRATION AND DISCHARGE

FORMULA	CONC. PPM	UNIT DISCH LBS/SEC/FT	DISCHARGE TONS/DAY
SCHOKLITSCH	382.93	0.2400	2820.18
KALINSKE	77.61	0.0486	571.55

* *

Run number 3. Output from data file REPT2 DAT with only totals listed.

NIOBRARA RIVER NR CODY, NE

TOP WIDTH	70.00 FEET	WATER SURF. SLOPE	0.0012500 FT/FT
MEAN DEPTH	1.56 FEET	D50	0.276 MILLIMETERS
MEAN VELOCITY	2.15 FT/SEC	KINEMATIC VISCOCITY	0.00001081
WATER DISCHARGE	234.78 CFS	SED. FALL VELOCITY	0.1228 FT/SEC
WATER TEMPERATURE	20.0 DEG C		

COMPUTED BED-MATERIAL CONCENTRATION AND DISCHARGE

FORMULA	CONC. PPM	UNIT DISCH LBS/SEC/FT	DISCHARGE TONS/DAY
LAURSEN	SIZE FRACTION DATA NOT GIVEN		
ENGELUND & HANSEN	1125.46	0.2359	713.44
COLBY	316.97	0.0664	200.93
ACKERS & WHITE (USING D50)	531.83	0.1115	337.13
ACKERS & WHITE (USING D35)	D35 NOT GIVEN		
YANG SAND (USING D50)	604.59	0.1267	383.25
YANG SAND (USING SIZE FRACTIONS)	SIZE FRACTION DATA NOT GIVEN		

COMPUTED BEDLOAD CONCENTRATION AND DISCHARGE

FORMULA	CONC. PPM	UNIT DISCH LBS/SEC/FT	DISCHARGE TONS/DAY
SCHOKLITSCH	SIZE FRACTION DATA NOT GIVEN		
KALINSKE	SIZE FRACTION DATA NOT GIVEN		
ROTTNER	266.66	0.0559	169.04

* * * *

SUPPLEMENTAL DATA--SECTION G.

LOADING AND RUNNING THE PROGRAM ON THE PRIME COMPUTER

After the FORTRAN source code for the two programs (DISDATA.F77 and SEDDISCH.F77) have been entered into the Prime computer, they need to be compiled and loaded before they can be run.

Compiled programs DISDATA.BIN and SEDDISCH.BIN are created by entering and executing in sequence, the commands F77 DISDATA and F77 SEDDISCH.

The compiled programs are loaded by entering and executing the following command sequences:

```
SEG -LOAD                    and    SEG -LOAD
$ LO DISDATA                        $ LO SEDDISCH
$ LI                                $ LI
LOAD COMPLETE                       LOAD COMPLETE
$ Q                                 $ Q
```

Files DISDATA.SEG and SEDDISCH.SEG are created.

The command SEG DISDATA or SEG SEDDISCH is entered and executed to run the desired program.

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